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ANNUAL REPORT

OF THE

MISSISSIPPI RIVER COMMISSION

FOR THE

FISCAL YEAR ENDING JUNE 30, 1890;

BEING

APPENDIX W W

OF THE

ANNUAL REPORT OF THE CHIEF OF ENGINEERS FOR 1890.

C. B. COMSTOCK, Colonel, Corps of Engineers, Bvt. Brig. Gen., U. S. A.,
President,
CHARLES R. SUTER, Lieut. Col., Corps of Engineers, U. S. A.,
O. H. ERNST, Major, Corps of Engineers, U. S. A.,
MR. HENRY L. WHITING, Asst. U. S. Coast and Geodetic Survey,
MR. B. M. HARROD, Civil Engineer,
MR. HENRY FLAD, Civil Engineer,
MR. ROBERT S. TAYLOR,
Commissioners.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1890.

~~W. 2185~~
Eng 1010.5

1893, Dec. 15.

Captain Carl Pairfrey,
St. Louis, Mo.

[To be inserted at page 3083, Part 4, Annual Report Chief of Engineers, 1890.]

ERRATA: REPORT OF THE MISSISSIPPI RIVER COMMISSION, BEING APPENDIX W W, ANNUAL REPORT CHIEF OF ENGINEERS, 1890.

Page 3084.—Under Surveys and Examinations, fourth line, for complete read completed.
Under General Service, ninth line, insert with before thirty-eight.
Page 3085.—Eleventh line, insert is before asked for.
Page 3086.—Under Second district (*b*), second line, for plan read place.
Page 3087.—Ninth line, for District read Districts.
Under Third district, second line, for Russell read Rossell; eleventh line for resulting read resulted.
Page 3088.—Under (*d*), ninth line insert still before caving.
Under A, third line, insert Ark. after Lakeport.
Page 3091.—Under A, eighth line, for timbers read timber.
Page 3092.—Under List of Appendices, C, for report read reports.
Page 3093.—Under List of plates accompanying the foregoing report, reference to the photographic plates Nos. 5 to 33, Appendix F, is omitted; also three photographic plates in Appendix I are not listed.
NOTE.—No MS. copy of this list has been received.
Page 3094.—Eleventh line, for 9⅛ read 9½.
Table, fourth column, for Quatrelle read Quatrelli.
Seventh line below table, for 1754 read 1757.
Tenth line below table, for statement read table.
Nineteenth line below table, for Maggione read Maggiore.
Twenty-first line from bottom, for Parma, Cremona read Parma-Cremona.
Nineteenth line from bottom, take out quotation marks at beginning of line.
Fifteenth line from bottom, take out quotation marks at beginning of line and complete quotation mark before arise.
Page 3095.—Tenth line below table, for rise read increase.
In General Wilson's letter, fourth line, for banks read sides.
Fifth line in same, for points read places.
Seventh line from bottom take out old.
Page 3096.—Under (1) Cairo, fifth line, for 1.0 read —1.0.
Under (3) Helena, second line, add Dec. 26, 1872, 0.00.
Page 3097.—Twenty-fourth line, insert in part after probably due.
Twenty-sixth and twenty-seventh lines, for 18 read 24.
Twenty-eighth line, for 69 read 73, and for sixty-ninths read seventy-thirds.
Page 3098.—First line, for country read century.
Eleventh line, for straight read straighter.
Seventeenth line, after stable regimen insert suited to its sediment.
Nineteenth line, after deep water insert So Bayou La Fourche, needing a high slope for stable regimen when its waters fall to the level of swamps but a few feet above gulf level, builds up its bed, necessitating high levees.
Nineteenth line, insert too after so.
Twenty-sixth line, for waters read water.
Page 3099.—9—8 lines from bottom, for subsidenee read subsidence.
Page 3103.—Twenty-first line from bottom, for charge read overcharge.
Page 3105.—Eighteenth line from bottom, for discharges read discharge.
Page 3106.—Second line after each insert river.
Sixth line, for dividing rivers read dividing the river.
Twentieth line, for main read original.
Page 3107.—Appendix C. Headline for Report for read Reports of.
Page 3112.—Appendix E, first line of text, for operation read operations.
Page 3113.—Thirteenth line, for 18 7 read 1887.
Page 3118.—First column, second line, for * substitute †.
Last line, for the north read and north.
Page 3119.—Fourteenth line in the report, for Tuttle read Turtle.
Page 3120.—Last column, eighth line, for 1881 read 1882.
Page 3123.—Section 19, tenth column, for 1: 1.24 read 1: 2.24.
Page 3124.—Section 35, eleventh column, for 279 00 read 279 30.
Section 40, fourth column, for 191, 433 read 191, 453.
Section 58, eleventh column, for 224 26 read 224 20.
Page 3125.—Section 85, last column, for 22,590 read 22,500.
Section 88, last column, for 22,709 read 22,700.

Page 3125.—Section 93, fifth column, for 3,442 read 3,482.
Page 3126.—Section 108, third column, for 25,206 read 25,200.
Section 108, tenth column, for 1: 1.21 read 1: 2.21.
Section 127, thirteenth column, for 16,000 read 16,900.
Page 3127.—Section 137, twelfth column, for 69 37 read 59 37.
Section 183, tenth column, for 1: 3.22 read 1: 1.32.
Page 3128.—Section 199, twelfth column, for 10 08 read 10 18.
Page 3130.—Section 35, fourth column, for 25.7 read 27.7.
Section 36, fourth column, for 27.7 read 25.7.
Page 3132.—Section 155, eighth column, for 71.6 read 81.6.
Section 156, eighth column, for 85.0 read 75.0.
Page 3133.—Section 242, fourth column, for 55.9 read 25.9.
Section 244, fifth column, for 58.7 read 53.7.
Section 246, eighth column, for 57.5 read 75.5.
Section 256, eighth column, for 27.0 read 77.0.
Section 265, seventh column, for 43.3 read 43.2.
Page 3134.—Section 306, fourth column, for 24.4 read 34.4.
Page 3135.—Section 394, sixth column, for 3,466 read 3,460.
Section 402, sixth column, for 2,270 read 2,770.
Page 3136.—Section 471, fifth column, for 100.9 read 109.9.
Section 475, seventh column, for 78.1 read 75.1.
Section 492, sixth column, for 2,268 read 2,263.
Page 3137.—Section 519, sixth column, for 2,187 read 2,189.
Page 3138—Third column, at Memphis and Chotard Ldg. insert "0.0" in each case.
Page 3139.—In table, column of lowest water, opposite White River, Natchez, and Red River Ldg. insert "0.0" in each case.
Page 3140.—In table, third line, for on read or.
Page 3142.—Eighteenth line, after doing insert during.
Page 3144.—In table, third column, opposite St. Joseph and Port Hickey insert "0."
Page 3145.—Fifth line, second column, for * substitute †.
Page 3149.—Mean velocity, Old River, Jan. 9, for 2.257 read 3.257.
Page 3152.—In formula for stages between 15 and 20 feet complete the parenthesis thus: $+(20-h)$.
Page 3155.—Feb. 14, in column of "scour or fill" for * substitute ‡.
Feb. 16, mean velocity, for 4.481 read 3.481.
Page 3157.—The headings in columns of "water area," "scour or fill," "mean velocity" and "discharge," should read *square feet* in the first two and *feet* and *cubic feet*, respectively, in the last two.
Page 3160.—Dec. 1, mean velocity, for 5.381 read 4.381.
Dec. 29, mean velocity, for 4.120 read 4.129.
Page 3161.—Jan. 1, maximum depth, for 3.0 read 63.0.
Page 3162.—March 6, area below datum for 165,511 read 160,511.
Page 3163.—April 22, discharge, for 423,969 read 423,069.
Page 3165.—In table, value of *b*. Dec. 4, for 0.1943 read 0.1953.
In table, last line, for 1800 read 1889.
Page 3167.—Feb. 23, mean velocity, for 4.405, read 3.405.
Page 3168.—March 7, discharge, for 849,723 read 749,723.
Page 3169.—April 4, maximum depth, for 45.0 read 75.0.
Page 3173.—Jan. 31, reading of local gauge, for 29.69 read 29.60.
March 24, number of velocity stations, for 12 read 11.
Page 3174.—Jan. 13, mean depth, for 48.8 read 48.4.
Jan. 29, discharge, for 948,073 read 958,073.
Page 3175.—Feb. 5, fill, for + read —.
Feb. 18, rise or fall, insert "0.0" in blank space.
Page 3176.—March 4, the mean velocity, discharge, and total discharge should be 5.773, 1,067,372, and 1,098,372, respectively, instead of as printed.
April 2, mean velocity, for 5.489 read 5.849.
April 5, mean velocity, for 3.732 read 5.732.
April 4, water area, for 195,501 read 196,501.
Page 3177.—April 26, area below datum, for 192,252 read 192,352.
May 6, area below datum, for 199,854 read 190,854.
April 30, mean depth, for 49.6 read 49.9.
May 7, water area, the following note should be inserted: Adopted from field computation, as sounding notes are incomplete.
Page 3179.—Second paragraph, first line, for continued read continuous.
Third paragraph, second line, take out hyphen after the figure 7.
Page 3182.—Fifth line, for that read than.
Twentieth line, for territory read tertiary.

Page 3183.—Under levels, third paragraph, last line, for 2 feet read 0.2 foot.
Page 3185.—First table, last line, fourth column, insert "0.000" in blank space.
Page 3186.—Second paragraph, fifth line, for chalking read calking.
Page 3187.—First district, balance of funds, for 12,155.22 read 12,165.22.
Page 3188.—Columbus, amount in Treasury, for 6,150.72 read 6,150.92.
Page 3189.—Third district, third line, second column, for 380,410.84 read 390,410.84.
Page 3194.—First district, third column, opposite gauges, for 2,500 read 2,000.
Memphis Reach, eighth column, for 13,500.90 read 13,500.00.
Memphis Reach and Harbor, fourth column, for 138,282.94 read 138,232.94.
Page 3195.—Levees, Yazoo Front (Ben Lomond), sixth column, for 11,385.22 read 11,386.22.
Twelfth line, after Existing works insert protection of.
Page 3199.—Fourth line, for two in approximately straight lines read in two approximately lines.
Page 3200.—Fifth line, omit , after Island.
Twenty-second line, for at depths read of depths.
Forty-third line, for The depths read These depths.
Page 3201.—Under Money statement, first line, for July 1 read June 1.
Page 3202.—Under Plum Point Reach, third column, for 262,910.55 read 262,901.55.
Page 3203.—Under Hickman, Ky., last column, for 48,647.78 read 48,647.76.
Under First district, first column, for Hunter & Trey read Hunter & Frey.
Page 3204.—Opposite No. 5, for Highman read Hickman.
Page 3207.—Under Grand total, Amt., ninth line, for 71,775 read 11,775.
Page 3209.—Opposite Work done, insert feet after 2,717 square.
Page 3210.—Second table, first line, third column, for 31.1 read 31.0.
Page 3211.—Appendix G, fifth line of text, for 130 miles read 180 miles.
Under Memphis Harbor, fourth line, for in the read in their.
The same, fourteenth line, for grass read gross.
Page 3213.—Under Details of Construction, ninth line, for undetermined read undermined.
Page 3216.—In the high-water table, sixth line, for 1889 read 1887.
The same, seventh line, for Mhoen's read Mhoons, and for 1.76 read 1.70.
Page 3217.—Seventh line, for known point read known at that point.
Eighth line, for was 1.15 read was by 1.15.
In the New Madrid table, heading of fourth column, for secood read second.
Page 3218.—In the Memphis table, under Area, Mar. 26, for 147,637 read 146,637.
Page 3220.—Seventeenth line, for conclusion, if reached read conclusion is reached.
Page 3221.—Twenty-first line, for quantitively read quantitatively.
Twenty-fourth line, insert the before restraint.
Thirty-seventh line, for at the flood read of the flood.
Fifth line from bottom, for Hushpuckena read Hushpuckana.
Page 3223.—Heading of next to last table for Survey read Surveys.
Page 3224.—Under Money statement, last column, for 42,771.43 read 42,777.43.
Page 3228.—First table, third line, under Compensation, for 130 read 120.
Second table, third line, under Exports, for 369 read 360.
Second table, thirteenth line, under Exports, for 5,951 read 5,921.
Second table, under Exports, Total, for 93,898 read 93,897.
Page 3231.—Twenty-seventh line from bottom, for the seare read these are.
Page 3233.—Sixth, twelfth, and fifteenth lines from bottom, change comma to decimal point before last two figures in each case.
Page 3235.—Second line, for Vicksburgh read Vicksburg.
Fifth line from bottom, for 40,550.40 read 40,550.49.
Page 3236.—Twenty-eighth line from bottom, for guarantied read guaranteed.
Page 3238.—Fifteenth line from bottom, for link-leather read link leather.
Page 3241.—Sixth paragraph, last line, for 1880 read 1889.
Page 3242.—Thirteenth line from bottom, insert $ before 1.27½.
Page 3250.—First table, third line, under cost, for 1,496.65 read 1,495.65.
Page 3252.—First table, under Greenville Reach, sixth line, insert of after cost.

Page 3253.—In table, eighth line, for 3¼ read 3½.
The foot-notes are printed on page 3254.
Page 3255.—Twentieth line from bottom, for March 21 read March 31.
Page 3265.—Second table, for Apr. 24 read Apr. 25.
Page 3267.—First table, second line, last column, for 96 read 94.
Second table, fourth line, second column, for 1,657.34 read 1,667.34.
Page 3268.—Seventeenth line from bottom, for Filcher's read Pilcher's.
Eighth line from bottom, for 30 read 20.
Page 3269.—Third line, for slide read side slope.
Twenty-sixth line, for direction read directions.
Ninth line from bottom, for surface read seepage.
Fifth line from bottom, for crevasses read of a crevasse.
Page 3272.—Thirteenth and thirty-sixth lines, for Sterling read Starling.
Page 3273.—Twenty second line, last word, for at read a.
Thirty-fifth line, for number of read numberless.
Twenty-second line from bottom, for floods read flood.
Page 3276.—Report of Mr. J. J. Hoopes, second line, for or read of.
Page 3277.—Table opposite Apr. 11, last column, for 212,497 read 212,479.
Page 3278.—Second table, in discharge at Luna, Mar. 25, put comma instead of decimal point after second figure.
Page 3279.—Opposite Boggy Bayou, under Remarks, for Apr. 3 read Apr. 9.
Opposite Chicot, under Date of observation, for Apr. 11 read Apr. 17.
Opposite Drainage openings, under Remarks, for 248,600 read 148,600.
Opposite Lower side of Catfish, in column of Dates, inclose the four double dates, thus: { Apr. 11. / Apr. 13. }
Opposite Easton, under Discharge, for 52,296 read 55,296.
Page 3280.—Opposite Skipwith's, Apr. 2, under "method used" change do. to Meter.
Page 3281.—Table, Jan. 31, under Total, for 2,050 read 1,050.
Table, heading of fifth column, for on read in, and omit 5.
Page 3282.—Second table. Apr. 17, under area, for 42,095 read 42,075.
First table, heading of fifth column, for on read in, and omit 5.
Page 3283.—Tenth line, after apportioned, insert as follows:
Under the last two financial statements, after the footing insert Balance, June 30, 1890, 0.00.
Page 3284.—Under the last three financial statements, after the footing insert Balance, June 30, 1890, 0.00.
Page 3285.—Fifth paragraph, fourth line, for July, 1890, read July, 1889.
Sixth paragraph, fourth line, for begin read begun.
In heading, for Fred. F. Spalding read Fred. P. Spalding.
Page 3287.—Second line, for works read work.
Under Financial statement, fifth line, insert levees before Lake Bolivar Front.
Page 3288.—Fourth line, for lists read list.
Page 3289.—Under the construction of levees, etc., twentieth line, for the channel read this channel.
Page 3291.—Eleventh line from bottom take out the period after first word.
Page 3292.—First line, put period instead of comma after height.
Page 3293.—Second line from bottom, for 13,500 read 18,500.
Page 3295.—Fifteenth line, for permitted read permit.
Nineteenth line from bottom, for 4.373 read 4.378.
Eighteenth line from bottom, after water-surface insert at the crevasse.
Page 3297.—First paragraph, last line, for 4.82 read 4.2.
Page 3300. Under No. 15, eighth and ninth lines, take out hyphen after horse-shoe and after V.
Last paragraph, third line, after It was insert in.
Page 3301.—Table, second line, under Depth, for 3.5 read 8.5.
Table, opposite No. 4, under High-water mark, for 1.8 read 1.6.
Table, opposite No. 30, under Velocity, for 1.3 read 1.8, and under Amount raised, for 2.9 read 2.0.
Page 3302.—Table, opposite Lobdell, under Width, for 1081 read 1981.
Page 3304.—Second line from bottom, for 8 read 6.
Page 3307.—Seventh line, for harbors read harbor.
Page 3309.—Sixteenth line, insert by them after overflow.
Fourteenth line from bottom, for 1883 read 1889.

Page 3310.—Second paragraph, second line from bottom, for 64.301 read 64,301.
Page 3312.—Second line, for 2,000 read 2,900.
Twelfth line, for 1885 read 1883.
Second line above the heading Gauges, for those read these.
Page 3313.—First table, March 5, under Discharge, for 1,251,659 read 1,251,639.
Page 3315.—Under Money statement, last table, after third line insert July 1, 1890, outstanding liabilities, 0.
Page 3316.—In List of civil engineers, time of W. G. Price at Simmsport, on discharge observations, for 2 months, 1½ days read 21½ days.
Seventh line from bottom, for The space read This space.
Page 3319.—Twenty-first line, for continued read continues.
Twenty-sixth line, for that read this.
Under Hardscrabble Levee, fifth line after levee insert was used to raise the river crown and as a result the levee.
Page 3320.—Under L'Argent to Rifle Point, seventh and eighth lines, for rotton read rotten.
Ninth line from bottom, insert it before difficult.
Page 3321.—Nineteenth line, for were read was.
Page 3326.—Under Panola, second line, for building read buildings.
Under Concordia and Fletcher, third line, for sea read seep.
Page 3330.—Under Cost and material were, fifth line, for 3 by 6 feet read 3 by 6 inch.
Fifteenth line from bottom, for Gouldsborough read Gouldsboro.
Page 3332.—Fifth line, insert inch after 3½.
Eighteenth line from bottom, for Spur No. 3 read Spur No. 2.
Seventh line from bottom, for $45.21 read $54.21.
Page 3333.—Eleventh line, for 119.40 read 11,940.
Second line from bottom, for 40 by 136 read 40 by 145.
Page 3334.—Eleventh line, for $2,513.78 read $1,513.78.
Page 3337.—Under Surveys, second line, after Morganza insert Reach.
Page 3346.—Under Stonewall or Lanaux crevasse, last line, for in levee read of levee.
Page 3347.—Under Preston crevasse, eleventh line, for 4 by 4 feet read 4 by 4 inch.
Page 3354.—Fifteenth line from bottom, for 1880 read 1890.
Seventh line from bottom, for hauled read handled.
Page 3355.—Tenth line, opposite Wrapping paper, for 672 read 679.
Page 3356.—Sixteenth line from bottom, opposite Wooden-ware, for 3,509 read 3,500
Page 3357.—Twelfth line, opposite Groceries, for 352,032 read 52,032.
Thirteenth line, opposite Wooden-ware, for 2,030 read 32,030.
Under Articles of cargo, opposite corn, for 14,895 read 14,896.

O

EXTRACT FROM THE ANNUAL REPORT OF THE CHIEF OF ENGINEERS TO THE SECRETARY OF WAR.]

OFFICE OF THE CHIEF OF ENGINEERS,
UNITED STATES ARMY,
Washington, D. C., October 4, 1890.

* * * * * * *

MISSISSIPPI RIVER COMMISSION.

This Commission, organized under the provisions of the act of Congress of June 28, 1879, reports to and receives instructions from the Secretary of War through this office.

The report of the Commission for the fiscal year ending June 30, 1890, embracing the following subjects, viz: (1), Surveys and examinations; (2), Construction; (3), Financial Statement; and (4), Estimates, will be found in Appendix W W.

The estimate of funds required for the service of the Commission for the fiscal year ending June 30, 1892, is stated in the above-mentioned report as follows:

ESTIMATE OF FUNDS FOR THE MISSISSIPPI RIVER COMMISSION FOR THE FISCAL YEAR ENDING JUNE 30, 1892.

For salaries, inspections, and traveling expenses of the Mississippi River Commission; for printing and telegraphing; for office expenses and miscellaneous	$35,000
For surveys and examinations of the Mississippi River from the Head of the Passes to its headwaters, continuing survey	150,000
For improving the Mississippi River from the Head of the Passes to the mouth of the Ohio River	4,000,000
For work at—	
Hickman, Ky	111,250
Greenville, Miss	350,000
Vicksburg, Miss	175,000
Natchez, Miss	250,000
New Orleans, La	200,000
Red and Atchafalaya rivers	350,000

* * * * * * *

APPENDIX W W.

ANNUAL REPORT OF THE MISSISSIPPI RIVER COMMISSION FOR THE FISCAL YEAR ENDING JUNE 30, 1890.

THE MISSISSIPPI RIVER COMMISSION,
PRESIDENT'S OFFICE,
New York, June 30, 1890.

SIR: The Mississippi River Commission submits herewith its annual report for the fiscal year ending June 30, 1890.

At the date of its last annual report, for the reasons therein stated, no large amount of work had been done by the Commission under the appropriation contained in the river and harbor act of August 11, 1888. During this year the work has been vigorously prosecuted and, with the exception of some of the special local appropriations, the appropriations are now practically exhausted.

During the most of the year the Commission has not had sufficient funds available for its own expenses; to hold meetings or to obtain by personal inspection of the works the knowledge of their condition indispensable to an efficient supervision.

It had been expected that considerable balances would be available during the coming low-water season for the prosecution of the works, especially at Lake Providence; but the flood of 1890 supervened and threatened the destruction of levees from Helena to New Orleans, which were of greater strength and in better condition than ever before. Nearly all balances available were diverted to holding these levees (some of them constructed by the United States) in order to save the expense of their reconstruction and the widespread injury that would be done to all the lands behind them in case they should break. About $220,000 was diverted from other balances and applied to this purpose. While the attempt was not entirely successful, the extent of the disaster was largely reduced by the exertions of the local authorities and by the use of the funds supplied by the Commission. Out of an aggregate length of levees on the Mississippi below Cape Girardeau, amounting, when the flood began, to 1,294 miles, the aggregate amount of breaks during the flood was but 6.5 miles. The district officers were energetic and untiring in their endeavors to hold the levees. The important breaks were all below the Arkansas River, and from that point to New Orleans, with the exception of Vicksburg, the river was higher than ever before known.

If the flood be considered as to its maximum discharge, it was also a great one, though not as great as that of 1882. Captain Leach estimates the maximum discharge across the parallel of Helena at 1,617,000 cubic feet per second, and as 231,000 cubic feet less than that of 1882. Captain Young estimates the maximum discharge at Arkansas City, including crevasse escape, at 1,721,000 cubic feet per second on April 13,

1890. In 1882 it was estimated at about 2,000,000 cubic feet per second. Captain Kingman estimates the maximum flow across the parallel of latitude at the mouth of the Red River at 2,031,587 cubic feet per second on May 7, 1890. In 1882 it was estimated at 2,200,000.

Much valuable information in reference to the flood of 1890 will be found in the reports of the district officers. The lesson taught by the flood is the same as that of other great floods, namely, the necessity of raising and strengthening the levees.

The survey of the Mississippi River has been continued. Under the wording of the appropriations, it is not specifically under the control of the Mississippi River Commission, although the Secretary of War has so assigned its expenditure. Since the investigations made in this survey are, some of them, especially necessary to the Commission, the appropriations might well be among the Commission appropriations, as was formerly the case.

As to the results obtained by the expenditure of the last appropriation, it may be said that in general the work done by the Commission during the year has been successful, and is producing the results desired. In the improved part of the Plum Point Reach, the least navigable depth in 1888 was 13.5 feet, and in 1889 10 feet. In that part of the Lake Providence Reach where work has been done, the least navigable depth in 1888 was 9 feet, and in 1889 8 feet.

A detailed account will now be given of the work done in the last year, supplemented by appendices containing the reports of the officers in immediate charge of the works.

SURVEYS AND EXAMINATIONS.

This work has been in charge of Capt. C. F. Powell, Corps of Engineers, the secretary of the Commission. During the year the survey of the Mississippi has been completed from Chester, Mo., to Alton, Ill. The triangulation is complete to Keokuk, Iowa, and the precise levels to Fulton, Ill. Editions of 36 sheets of the $\frac{1}{20000}$ map of the Mississippi River have been printed, numerous discharge observations have been re-computed, and much miscellaneous work has been done. For details see Captain Powell's report, Appendix E.

GENERAL SERVICE.

This has been in charge of Capt. C. F. Powell, and the work has been mainly confined to the delivery of stone to various works and to building barges. There were delivered to the first and second districts 19,134 cubic yards of stone. The barges under contract at the last report were completed and ten new barges built. Repairs were made to the general service steamers.

The towage cost of stone and coal by the general service has been computed for the seven years ending December 30, 1889, at 6.2 mills per yard-mile, thirty-eight months of work and forty-six months of suspension. The relative cost of towage in the low water of 1888 and the high water of 1889 was found to be 2.8 mills per yard-mile for the former and 2.4 mills for the latter. For details see Captain Powell's report, Appendix E.

First district.

(Cairo to foot of Island No. 40, 220 miles. Officer in charge, Capt. S. S. Leach, Corps of Engineers, U. S. Army. Headquarters, Memphis, Tenn.)

(*a*) *Columbus, Kentucky, 21 miles below Cairo.*—The expenditures at this point have been from specific appropriations in the acts of 1886 and

1888, amounting together to $43,750. The approved project provided for a revetment of 5 spur-dikes to protect about 2,200 linear feet of bank threatened by caving.

The same plant being used at Hickman and Columbus, only preliminary work was done at the latter place before completion of the work at Hickman. Construction was begun early in December, 1889, and continued under difficult conditions of river and weather for nearly a month, when the approach of high water caused it to be suspended, one-half the work being accomplished. It is expected that operations can be resumed in time to complete the protection during the summer. No further appropriation asked for.

(*b*) *Hickman, Kentucky, 36 miles below Cairo.*—Caving has been going on at the upper part of the town, and about 1,000 feet of the bank has been protected, the upper end of the mattress revetment resting on a hard point of indurated clay. The expenditure has been from specific appropriations in the acts of 1886 and 1888, amounting together to $88,750. The form of the shore and the character of the strata of which it is composed compelled the adoption of special methods of anchorage and of grading, and gave the work a somewhat higher cost than usual. The mattress was begun October 4 and finished October 24, 1889, the cost of the work being $24.10 per linear foot. It does not appear that any displacement has occurred during the flood of this year.

Above the clay point already referred to, the alluvial bank is caving rapidly; but until the clay point wears away, which may not be for several years, the caving at the upper end of the town can be stopped with the balance of the appropriation remaining on hand. Should Congress deem it advisable to carry the protection along the low bottom above the clay point $111,250 additional would be needed.

(*c*) *Plum Point Reach, 147–186 miles below Cairo.*—(1) *Fletcher's Revetment.*—The allotment for this work from the appropriation of 1888 was $131,000. The approved project was for the construction of 7,400 feet of mattress revetment in five sections, of which there remained unfinished at the time of the last annual report 2,100 feet, in two sections. Work on these sections was begun towards the close of May, and after some delays due to the stage of water in June and July, was finished by the middle of September, 1889.

The 7,400 feet of revetment constructed in the two seasons is distributed along a distance of nearly 13,000 feet, the upper part being 3,000 feet in continuous length, and the lower part being divided into four sections, each 1,100 feet in length, and separated by intervals of 300, 400, and 500 feet. Between these two parts is a space of 3,800 feet, near the middle of which a false point formed by a piece of old work, until recently projected into the river. This interval was left unprotected in order that the point might cave back to the line of the new work. This caving took place during the high water of 1890, and it is proposed that the upper section of revetment be extended down stream to cover this part of the bank.

The experiment has been tried at the lower part of this bank protection of revetting lengths of 1,100 feet of bank, leaving intervals of 300 to 500 feet between them unrevetted, to see if this would give an efficient bank protection while reducing cost. Thus far the protection seems to be sufficient, but the test has not yet been long enough to enable final conclusions to be drawn.

(2) *Plum Point Revetment.*—A piece of mattress revetment 800 feet long has been placed half a mile above Plum Point Landing to check caving that threatened the stability of the crossing just below.

(3) *Daniell's Point Revetment.*—As rapid caving was going on in the bend above Daniell's Point, which threatened to disturb the regimen of the river below, its protection was undertaken. The approved project provided for a revetment of about 5,000 feet in length, at an estimated cost of $100,000. The work as completed January 14, 1890, forms a continuous protection of 5,300 feet from the extreme point up, and is designed to fix the channel of the river, which was in danger of deteriorating from the caving at the point and in the bend above. To meet the great strain to which it would be subjected the work was heavier than usual, and was constructed with especial attention to details. The cost per foot was therefore relatively high, being about one-third greater than that of the continuous portion of the Fletcher revetment.

(4) *Elmot and Island No. 30 Dikes.*—As noted in the last annual report, this work was suspended after the greater part of the foot mat was laid, because of the low stage of water in 1889. It was resumed in February, 1890, and after some interruption by high water is now within a few days of completion.

Results.—The least low-water depth through the part of the Plum Point Reach which has been improved was 13.5 feet in the very low-water year 1888, and 10 feet in 1889. This improvement on the original low-water depth of about 5 feet is necessarily accompanied by a reduction in the steep low-water slopes which formerly existed over the bars. The low-water fall from Daniell's Point to Craighead Point, a distance of 20 miles, was about 2.8 feet less in 1889 than in 1879.

For details of work in the first district, see report of Captain Leach, Appendix F.

Second district.

(Foot of Island No. 40 to mouth of White River, 180 miles. Officer in charge, Capt. S. S. Leach, Corps of Engineers, U. S. Army. Headquarters, Memphis, Tenn.)

(*a*) *Memphis Reach, 226 miles below Cairo.*—But little work has been done during the year. In the original design of the system of dikes known as the "Citizens' Protection," it was expected that natural deposits of silt would replace the perishable brush. This natural accretion not taking place, it was decided to protect the uppper ends of the dikes with a covering of earth and pavement of stone, and this plan was carried out with four of the dikes. Dike No. 1, being of less importance, was left untouched, and is now entirely masked by earth dumped above it by various parties.

In consequence of the recession of Hopefield Point a bar has formed at the upper part of the harbor, cutting off access at low water to the levee above the elevator. A plan to remedy this difficulty is now before the Commission for consideration at their next meeting.

The only damage occasioned by the flood of this year is a fault of 500 feet in the upper work of Hopefield revetment, which will be repaired during the coming season.

The district officer submits an estimate for the fiscal year 1892 of $37,000 for Memphis Harbor.

(*b*) *Helena Harbor, 306 miles below Cairo.*—The approved project for this plan, under a specific appropriation of $75,000 in the act of August 11, 1888, provided for the protection of 3,000 feet of bank by 600 feet of continuous revetment in front of the elevator, and a system of five spur dikes further down, together with a drainage canal to carry off swamp water from the back of the levee. The canal was finished about the close of the last fiscal year, and the mattress work at the

evator in September, 1889. Dikes 1 and 2 are finished, the other three re still incomplete.

The dike construction was attended with unusual difficulties from the orce of the current and the interference of drift, and two floor mats i succession were lost at Dike No. 1. This with sliding of the bank om No. 4 to No. 5, which required extension of work at those dikes, ade it impossible to finish the protection within the appropriation. ifteen thousand dollars additional is needed to complete the work.

LEVEES, FIRST AND SECOND DISTRICT.

The levee at Laconia Circle, above the mouth of White River, was vertopped by the flood which was here 2 feet higher than any previusly recorded. The only break in these districts was a small one at ustin, Miss., 288 miles below Cairo. The plum Point levees were atched and cared for. Those near Helena were protected mainly by he local levee board. The Mississippi levees in the second district were ttended to exclusively by the State authorities.

For details of work in the second district, see report of Captain Leach, ppendix G.

Third district.

(Mouth of White River to Warrenton, Miss., 220 miles. Officer in charge, Capt. V. T. Russell, Corps of Engineers, U. S. A., to December 20, 1889; since then Capt. V. Young, Corps of Engineers, U. S. A. Headquarters, Memphis, Tenn.)

(*a*) *Lake Providence Reach.*—The work during the past year has been onfined to bank protection in Louisiana Bend. The approved project ontemplated the protection of about 4 miles of bank by a subaqueous mattress 260 to 300 feet wide, and an upper bank covering of riprap.

The work at this place is an exceedingly difficult one in consequence of the depth of water and swiftness of the current. An attempt at sinking the upper end of a mattress while weaving was continued at its lower end, resulting in its partial loss. On account, it is supposed, of the softness of the bank, several slips took place which necessitated the use of supplementary mattresses. These accidents, and the use of stone for the upper bank revetment, made the work done very expensive,—much more so than it should have been without these accidents, and hence not giving a just idea of the cost under ordinary circumstances.

The least depths in the year on the crossings of the reach affected by the works, were at Duncansby, 17 feet, Vista, 8.5 feet, and Stack Island, 11 feet. At Ben Lomond the depth went down to 8.5 feet, and to 7 feet at Ajax Bar, both crossings being below the works of improvement.

(*b*) *Vicksburg Harbor and Delta Point.*—The work here has two objects: First to hold Delta Point by revetment work and thus prevent its further recession, which would allow the Mississippi to abandon the present Vicksburg front entirely instead of partly, as is now the case; second, to form a dredged canal leading to a dredged basin whose bottom is to be 5 feet below low water at the upper part of the city of Vicksburg.

The Delta Point Revetment, covering 10,700 feet of bank, has so far been entirely successful, and has required no repairs during the past year. New work will probably be required to check caving above.

Dredging in Vicksburg Harbor has been continued this year, principally in the canal connecting the basin with the river below. As the work can be carried on only when the river is above mid stage, very little was done after the date of the last report, until February of the

present year. No appreciable fill had taken place in the basin in 1889, and that in the canal has been confined to a limited area. The dredging of this season, which is done partly by contract and partly by Government plant and hired labor, will probably reach a plane 8 feet above low water. The estimate of the local officer for the fiscal year 1892 is $175,000.

(*c*) *Greenville Harbor.*—In previous years ten spur-dikes have been built in front of the city, in part by the city itself, and with some repairs have held the front of the town satisfactorily from further caving. But caving has been going on above the dikes for a long distance, threatening ultimately both them and the city. A little work had been done above the city, but the partly completed revetment was much damaged by the high water of 1889. Instead of repairing and extending this mattress, it was decided to protect the bank by means of two crib-dikes at and below the site of the old mattress, and, by a pile-dike in the form of an obtuse salient, covering a caving-pocket just above the old system of spurs. Between these later constructions there remains a space of about 1,500 feet, and above the upper crib-dike about 5,000 feet, of exposed bank, all of which will need protection. The estimate of the local officer for the fiscal year 1892 is $350,000.

(*d*) *Lake Bolivar Front.*—A special allotment for this work was made by the river and harbor act of August 11, 1888. The object of the improvement is to stop the caving of the bank in front of the large and costly levee across the end of Lake Bolivar, which was threatened by the rapid encroachment of the river. During the latter part of 1888 and the beginning of 1889 a part of the bank immediately in front of this large levee was revetted. This work, so far as carried out, was perfectly successful in stopping caving; below the work the bank is caving rapidly.

The work done during the year consisted simply in repairing some of the revetment. The estimate of the local officer for the fiscal year 1892, is $100,000.

LEVEES, THIRD DISTRICT.

A.—*Construction.*—No work of construction has been done during the year except on the Tensas Front, a small enlargement below Lakeport in September, 1889, and raising sunken places in Whiskey Chute and Grand Lake levees in January, 1890, in anticipation of the flood.

B.—*Protection during high water.*—By the end of January it was evident that a considerable flood was to be expected, and an inspection of the whole line was made, with such repairs and strengthening as seemed urgent. The State and other levee organizations took up the work vigorously, and continued it until their means were exhausted; after the end of March the United States Government alone had funds for protection of levees in Louisiana in this district. The work in Arkansas, as heretofore, was under direct Government supervision. Mississippi asked for no aid, except in holding the ends of levees at crevasses.

The first break in the Tensas Front levees occurred March 9, 9 miles above Arkansas City, and the first on the Mississippi side at Offuts, March 18. Breaks occurred at seventeen places in this district, with an aggregate length of 3¾ miles.

Except in some minor cases it was found useless to attempt the closure of the openings, and efforts were confined to holding, by one or other device, the broken ends of the levees, and so checking the en-

largement of the breaks. Several plans were tried, with varying results; the most successful being the employment of spur-dikes made of piling, brush, and sacks of earth, to break and deflect the current, and mattresses to cover the broken ends of the levees and prevent further erosion.

The overflow limits on the right bank in this district included 3,050 square miles, of which all but 550 was under water. On the left bank the whole area within the overflow limit was near 2,000 square miles, of which 1,900 was under water. The United States boats, in addition to their other work, were employed in the relief of people in the flooded region.

Miscellaneous.—Discharge observations were made at Arkansas City and Wilson's Point, on the main river, and at the principal crevasses. The results indicate a maximum flow past the latitude of Arkansas City of about 1,700,000 cubic feet per second, of which 1,300,000 could be confined by the levees at their present grade.

Surveys were made of the Lake Providence Reach and of the Greenville Bends. These surveys indicate no immediate danger from cut offs except at Ashbrook Point, where the distance across the neck is now 2,400 feet, and is decreasing at the rate of 300 feet yearly. A cut-off here would shorten the river 8 miles or more.

For details of work in the third district see report of Captain Young, Appendix H.

Fourth district.

(Warrenton, Miss., to Head of Passes, 484 miles. Officer in charge, Capt. D. C. Kingman, Corps of Engineers, U. S. Army. Headquarters, New Orleans, La.)

(*a*) *Improvement at Natchez and Vidalia.*—The danger apprehended here is the formation of a cut-off across the point above the town. As its prevention would require the protection of a large amount of caving bank, its cost would be great; it has been estimated at $750,000.

No work has been done during the year in protecting caving banks or upon the proposed spur levee on Cowpen Point. Fears have been recently expressed by the citizens, and a survey will be made when the river shall have reached a suitable stage.

(*b*) *Rectification of Red and Atchafalaya rivers.*—The project here is to limit the flow down the Atchafalaya by means of dams submerged sufficiently to permit navigation over them, and, at stages below 10 feet, to make the Red River flow north of Turnbull's Island directly into the Mississippi by building a low dam on the west side of Turnbull's Island and a dike from its lower end to the Mississippi. Then at low stages the Atchafalaya will be an outlet of the Mississippi and will receive water from it alone. Until these works are completed attempts must be made to keep the mouth of the Red River open during low water by dredging.

Of the six submerged dams projected for the Atchafalaya, No. 1 had been finished and the sill of No. 3 partly laid by July 1, 1889. Since then No. 3 has been completed. Some changes will have to be made in these dams to equalize the high-water capacity of the water-ways over them; at present the high-water area over dam No. 1 is about one-fourth greater than that over dam No. 3, involving a concentration of fall at the latter place and a velocity unfavorable to navigation. These dams have remained intact through the flood.

The sill for the dam designed to deflect the low-water flow of Red River into the channel north of Turnbull's Island has been laid.

Dredging was carried on in Lower Old River during low water, with

the result of keeping the channel open throughout the season, although for a few days it was practicable only for small and light-draught boats.

The estimate for the fiscal year 1892 is $350,000.

(c) *New Orleans Harbor.*—The object of the work at New Orleans is to hold the river in its present position by protecting caving banks. As the depths are exceedingly great—in places as much as 150 feet—and in many places the banks very steep, the method of protection mostly used is that of spur-dikes about 1,000 feet apart, which, starting from near low water, project into the river, sloping downward in the direction of their length at the rate of about one foot vertical to three horizontal (or having a top slope of 1 : 3) till the slope reaches the river-bed. The project includes work in the bends at Carrollton and at the lower part of the city (third district), on the left bank, and at Greenville and Gouldsboro on the right. Prior to July 1, 1889, mattress revetment had been begun at Carrollton, but work had been stopped; a system of six spurs had been completed in Gouldsboro Bend, and one large spur partly finished in Greenville Bend.

During the past year the first spur at Greenville has been finished and a second built, and four spur-dikes have been built in the third district, completing the improvement for that point. No further caving has taken place, and so far as can be ascertained at the present stage of water the works have perfectly withstood the flood. In the third district, where the caving had encroached upon the street, the dikes were carried up over the batture and connected with the levee by paved embankments. Here the falling water shows a deposit of silt on the batture from 1 to 3 feet in thickness.

Six spurs remain to be built in the Carrollton Bend, where considerable scour is said to have taken place during the past flood, and where there may be heavy caving as the river falls. Materials in part are on hand, and work will be begun as soon as a proper stage of water is reached.

The estimate for the fiscal year 1892 is $200,000.

Surveys, examinations, and inspections.—Surveys have been made in the caving bends at Lakes St. Joseph, Bruin, and St. John to determine how far the levees crossing the ends of these lakes are endangered by the progressive caving. At the present rate of caving it appears that the Lake St. Joseph levees are safe for several years to come, unless the more rapid caving above should work down-stream. At Lake Bruin the rate of bank recession is such that the levee will be reached in about three years. At Lake St. John the caving is slow and the levee is not immediately threatened.

At Morganza crevasse there has been little or no change in the river cross-section since 1887, the water of the next two seasons not having been high enough to make the levee any factor in the river regimen.

Gauge records have been kept at several points and the results reported to the Secretary. Circulars asking for information about high-water marks during the flood of this year were distributed with the request that the answers be sent to the Secretary. So far as learned the flood, from New Texas Landing down to Hermitage, was from 1.2 to 1.9 feet above that of 1882.

A full set of high-water discharge measurements was obtained at Carrollton and one less complete at Red River Landing, and detached observations were made at Warrenton, Natchez, and Baton Rouge, as well as at Simmsport, on the Atchafalaya. Captain Kingman submits

the following estimates of maximum flow across the latitude of Red River Landing:

	Cubic feet per second.
Mississippi River, May 7	1,487,362
Atchafalaya River (between levees)	474,225
Atchafalaya River (crevasse escape)	70,000
Maximum passing latitude of Red River Landing	2,031,587

LEVEES.

A.—*Construction—Tensas Front.*—Since the last annual report the Hard Times-Wilson levee has been finished. This levee contains over 700,000 cubic yards of earth, and with protection levees and drainage ditches its construction involved moving nearly 800,000 cubic yards. The levee proper is a little over 10 miles in length, and with the protection levees about 11½ miles. It is the largest single levee built by the United States, and runs through a very difficult tract of country, swampy and covered with heavy timbers, and intersected by lakes and sloughs. It has not been damaged by the flood, though caving just above its upper end threatened in January to take it in flank.

B.—*Protection during high water.*—In November and December, 1889, a survey was made to ascertain the condition of the levees on the Tensas Front. The Hard Times Levee, at Lake St. Joseph Crossing, where it was low, was raised, and work on low places in Kempe Levee was carried on until interrupted by high water.

After the first allotment of $25,000 for protection of levees, March 12, a steamer and barge, with tools and materials, was sent to the Tensas Front and rendered valuable aid in protecting levees. Three breaks occurred in this part of the district, April 22 and 23, all in the vicinity of Natchez.

Below Red River the first important break was the Nita crevasse, on March 14, which gradually enlarged until its measured discharge was 400,000 cubic feet per second. In Pointe Coupée parish, from Smithland to Point Manoir, a distance of 40 miles, the levees were too low, and there is scarcely a mile in that distance upon which work was not necessary. To keep the water from their rear work was also needed on levees through to the Atchafalaya and down its left bank. The Morganza Levee, 8,000 feet long, was raised from 1 to 2 feet, and Grand Levee was raised about 1 foot. In spite of all efforts there were numerous breaks between April 20 and 23 in the district below Red River, the Morganza Levee being one of those broken.

As a rule the efforts of the Commission were directed to the prevention of breaks, and to checking the enlargement of those that occurred. To have attempted to close the crevasses at once would have required unlimited funds.

Detailed information in reference to the breaks in the levees during the flood will be found in Captain Kingman's report, Appendix I.

FINANCIAL STATEMENTS.

Appropriation for salaries and expenses Mississippi River Commission:	
Balance on hand June 1, 1889	$14,197.29
Received from transfers	394.80
Total	14,592.09
Expended from June 1, 1889, to June 30, 1890	14,475.59
Balance on hand July 1, 1890	116.50

Appropriation for deficiencies Mississippi River Commission:	
Balance on hand June 1, 1889	$4,214.39
Returned to Treasury	4,214.39
Appropriation for surveys of Mississippi River:	
Balance on hand June 1, 1889	51,965.16
Expended from June 1, 1889, to June 30, 1890	48,085.00
Balance on hand July 1, 1890	3,880.16
Appropriation for improving Mississippi River:	
Balance on hand June 1, 1889	1,876,031.16
Less expenses office Chief of Engineers	4,289.00
Balance, net	1,871,742.16
Refunded on sundry accounts	4.39
Total	1,871,746.55
Expended from June 1, 1889, to June 30, 1890	1,496,128.21
Balance on hand July 1, 1890	375,618.34

ESTIMATE OF FUNDS FOR THE MISSISSIPPI RIVER COMMISSION FOR THE FISCAL YEAR ENDING JUNE 30, 1892.

For the Mississippi River Commission: For salaries, inspections, and traveling expenses of the Mississippi River Commission; for printing and telegraphing; for office expenses and miscellaneous	$35,000
For surveys and examinations of the Mississippi River from the head of the passes to its headwaters—continuing survey	150,000
For improving the Mississippi River from the head of the passes to the mouth of the Ohio River	4,000,000
For work at—	
Hickman, Ky	111,250
Greenville, Miss	350,000
Vicksburg, Miss	175,000
Natchez, Miss	250,000
New Orleans, La	200,000
Red and Atchafalaya rivers	350,000

C. B. COMSTOCK,
Colonel of Engineers and Bvt. Brig. Gen.,
President Miss. River Commission.
CHAS. R. SUTER,
Lieut. Col. of Engineers, U. S. A.
B. M. HARROD.
R. S. TAYLOR.
O. H. ERNST,
Major of Engineers, Col. U. S. A.
HENRY FLAD.
HENRY L. WHITING,
Assistant U. S. C. and G. Survey.

The SECRETARY OF WAR,
Through the Chief of Engineers, U. S. A.

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APPENDIX A.

MEMORANDUM ON THE QUESTION WHETHER BUILDING LEVEES ALONG A RIVER CAUSES ITS BED TO RISE.

The statement is often made that leveed rivers raise their beds higher and higher as levees are raised, and hence that levees will give no permanent relief against overflow. These statements are usually made from theoretical opinions, and without a thorough knowledge of the theoretical side of the subject, and probably without any knowledge of the facts of experience, which alone can lead to conclusions entirely safe.

The river Po has long been leveed, and it is often stated that its bed has risen largely in consequence of levees. The following data will show how unfounded is the statement that the bed has risen by amounts that are of much importance:

At the revival of civilization the levees on the Po were complete and continuous from Cremona to the mouth of the Oglio, 94 kilometers, or 58.4 miles. About A. D. 1300 they were carried farther down the river, and in the succeeding centuries to near its mouth. In the present century levees have been systematized as to height. Four hundred kilometers, or 248½ miles, were below the flood of 1872; at the end of 1877 it was expected to reduce this to about 30 kilometers, or 18 miles. (Cenni monografici sull' idraulica fluviale in Italia. Roma, 1878.)

Zendrini, in 1720, observed an extreme low water at Ponte Lagoscuro, only 0.36 foot less than that of 1817; and at the dam of Governolo, near the mouth of the Mincio, the river was 1.3 feet lower than a stage of water of 1609, declared by Bardazzoli to be marvelous. (Lombardini Notizii.)

The Cenni Monografici gives the following:

Ponte Lagoscuro.

Period.	Mean lowest water.	Mean highest water.	Maximum high water.	Minimum low water.
1807–1825	3m.28 = 10.4 feet	7m.42 = 24.3 feet	8m.62 = 28.3 feet	0m.38 = 1 3 feet.
1826–1850	3m.26 = 10.3 feet	7m.38 = 24.2 feet	8m.96 = 29.4 feet	0m.72 = 2.3 feet.
1851–1875	3m.19 = 10.1 feet	7m.39 = 24.2 feet	9m.32 = 30.5 feet	0m.62=2.0 feet.

The above gauge-readings, which have only been kept since 1807, show that there has been no important rise of the bed of the river (since that could not rise without raising the low-water surface) at Ponte Lagoscuro in the sixty-eight years covered, and, in connection with Zendrini's observations, show that there has been no probable rise of any importance since 1720, although the raising of levees has been going on during this period.

Lombardini (Dei cangiamenti del Po, 1852, p. 17) examines this question for points above Ponte Lagoscuro, which itself is 92 kilometers (57 miles) above the mouth. He concludes that at Ostiglia, which is 183 kilometers (114 miles) above the mouth, the bed appears to have risen a few decimeters (decimeter = 3.9 inches) in a century, while at Governolo, 15 kilometers, (9½ miles) above, it appears to have been stationary for four centuries. In Il grande estuario Adriatico, 1868, App. D, he gives the following table of mean heights of extreme low waters above the lowest water known, which was in May, 1817:

Period.	Ostiglia.	Sermide.	Quatrelle.	Ponte Lagoscuro.
1817–1850	0m.55	0m.54	0m.47	0m.49
1851–1867	0m.44	0m.77	0m.84	0m.56

Comparing the means from 1817 to 1850 with those from 1851 to 1867, it will be seen that a small rise in low-water heights is indicated, but the observations at several stations in the first period were few, and hence the results are uncertain.

The flood heights have, however, steadily risen. The following greatest floods are recorded:

1705—1756 (in the year 1755)..... 1m.82= 6.0 feet
1754—1796 (in the year 1777)..... 2m.15= 7.1 feet
1797—1836 (in the year 1833)..... 2m.68= 8.8 feet
1837—1877 (in the year 1872)..... 3m.22=10.6 feet

From this statement it appears that the highest floods have increased in height since 1705 by 1.4 meters equal to 4.6 feet. The rise in flood heights on the Po has not been confined to the single point Ponte Lagoscuro, but has extended far above.

Gallizia (Giornale del genio civile, February, 1878) examines this question and gives the following result (the miles given are reckoned from the mouth of the river):

"At Bocca (394 kilometers equal to 245 miles), within the century, there is a progressive rise of 1.53 meters (5 feet), from 1801 to 1857. At Corossa (337 kilometers equal to 209 miles) the flood of 1801 read 6.35 meters, and their heights rose gradually to 7.95 meters in 1872, or to 7.45 meters, if allowance is made for a change of bed at this place. At Casal-Maggione (233 kilometers equal to 145 miles), from 5.60 meters in 1801, the floods rose gradually to 6.07 meters, in 1868, a rise of 0.47 meters (1½ feet). At Ostiglia (149 kilometers equal 73 miles), from 6.80 meters in 1801, and 7.50 meters in 1812, to 8.56 meters, although the river was not entirely confined. At Ponte Lagoscuro (92 kilometers equal 57 miles), from 2.19 meters *sopra guardia* in 1801, to 3.32 meters in 1872—the river not being entirely confined in this last year—a rise of 1.13 meters (3.7 feet); so that on the average there has certainly been a rise of more than a meter (3.28 feet) in the last seventy-five years along the whole course of the leveed river, excluding the Parma, Cremona front, where the levees are far apart, and the rise is abont one-half as much.

"Cenni monografici sull' idraulica, page 59, attributes the increased heights of the great flood of 1839 to "the more perfect leveeing of the Po and its tributaries, preventing the lateral escape of the waters, and sending in a canal to the sea that which previously flowed over the country.

"Lombardini (Il grande estuario Adriatico, p. 96) says the increased floods 'arise in part from levees, which hinder their spreading out, and also from the deforesting of mountain slopes."

Gallizia (*loc. cit.*) attributes increase of floods to deforesting, to the interest each one has to get rid of injurious water without consideration for those below him, to the leveeing of upper parts of rivers and their tributaries, and to the extension of the river mouth into the sea.

To sum up in reference to the Po, it may be said that during the present century the levees on the Po have been systematized and raised to follow an increase in flood height that in seventy-five years amounted to about 3 feet along the leveed portion of the river; and that there is some evidence of a small rise in the extreme low-water surface of the river, which may be caused by a rise of the bed. It should be noticed, however, that the rise in the bed (if it really exists) amounts to only two-hundredths of a foot a year, and that the annual cost of raising levees, to keep up with it, would be but a small part of the annual cost of a complete system of levees.

As to the rise in the flood level as the waters are more and more thoroughly confined, it may be said that this was a necessary result of confinement, that the same thing occurs on the Mississippi, and that it will cease when the levees have been built high enough to contain the greatest floods. On the Po thus far during the last seventy-five years the effect of the confinement of waters in raising the flood level has far exceeded any tendency that confinement may have had to reduce flood heights by scouring the bed.

The Rhine is also a river which, below Düsseldorf, has long been leveed, and if levees raise the bed of a river here they should have produced their full effect, as they are rarely broken.

The following table from Fijnje (Beschouwingen over eenige rivieren erste gedeelte, bijlage A, page 185) gives (in meters) the height of the lowest water which occurred in each ten years from 1772 to 1880, above the Amsterdam zero, for Cologne and Emmerich:

Period.	Cologne.	Emmerich.	Period.	Cologne.	Emmerich.
1772–1780	36.82	11.29	1831–1840	36.30	10.88
1781–1790	36.14	11.26	1841–1850	36.35	10.81
1791–1800	36.36	11.24	1851–1860	36.06	10.16
1801–1810	36.56	11.11	1861–1870	36.03	9.92
1811–1820	36.30	11.03	1871–1880	36.28	10.21
1821–1830	36.30	10.64			

It will be seen that the low-water surface appears to have fallen in the last hundred years at Emmerich, and possibly at Cologne.

Hagen (Wasserstände in den Preussischen Strömen, page 12) carefully examines the gauge-readings at Cologne from 1846 to 1879 and at Düsseldorf from 1800 to 1879 to detect changes in high and low water heights. Treating the gauge-readings by the method of least squares he found the most probable annual change in the water heights. At Düsseldorf he found that with great probability there was an annual sinking of the maximum high water in each year amounting to 0.3 inches; that the mean stage did not change, and that the annual lowest waters showed with some probability an annual rise of one-twelfth of an inch.

For Cologne he found that with great probability the high waters had sunk and the lowest waters had risen by about the same amounts as at Düsseldorf. A rise of one-twelfth of an inch in a year or 8 inches in a hundred years is so small as not to be an important matter in a system of levees, and if the hundred years of the table above are taken the rise disappears.

It has often been asserted that the bed of the Hwang-ho, or Yellow River of China, has risen above the surrounding country, where it is leveed. The error, originally due to Abbé Huc, has been repeated by English writers on China. The following extract from a letter to me by Gen. J. H. Wilson (a very competent authority) gives reliable information on the subject:

WILMINGTON, DEL., *May* 6, 1890.

* * * * * * *

In reply I hasten to say that I crossed the Yellow River on the 7th of January, 1866, near the city of Kai-fung-fu, in the province of Honan, and visited the site of the overflow of 1853, about 30 miles below Kai-fung-fu. I also traversed its embankments, or levees, on both banks of the river, visiting them and measuring them at various points between Kai-fung-fu and Chinan-fu, in the province of Shantung, taking observations, notes, and measurements, and having especially in view the repair and maintenance of the embankments, their present condition, and the effects produced by them. I had no instruments, however, except a hand-level, sextant, and tape-line, and could therefore make no accurate levels across embankments, bed of the stream, fore-shores, and adjacent plains; but the conclusion I came to in regard to the influence of the levees upon the bed of the river was that they had nowhere filled it to a higher level than the adjacent country. I had heard of Father Huc's narrative on that point, and I visited the place at which the river had left its old channel in 1853, leading to the sea south of the peninsula of Shantung, and made itself an absolutely new one to the Gulf of Pechili, north of that peninsula. Between this place—known on the maps of Asia (Keith Johnson's is the best) as Lung-mun-ku—and Kai-fung-fu the embankment was very large, but it was near the latter place that the great breach occurred two years ago. This was closed after incredible efforts and great expense, and the river forced to resume its old channel to the Gulf of Pechili, where it is now emptying itself, according to my advices of a

few months ago, and where it will most probably continue to empty itself till it can find a shorter line and steeper declivity to tide level.

By referring to my little book on China (Appleton & Co.) you will get other details.

In conclusion, I do not hesitate to say that I can not but believe that Abbé Huc was entirely mistaken in regard to the silting up of the channel, and that an exhaustive survey would prove beyond a doubt that no such silting as to raise any part of the bed above the adjacent country has ever taken place.

Yours, very truly,

JAMES H. WILSON.

The question of the rise of bed of the Mississippi will now be considered. Unfortunately it has not been studied as thoroughly as the Rhine and Po, and its gauge records go back but a few decades.

Levee building has gone on most rapidly since 1880, and as the river was very low in December and January, 1887-'88, and again in October and November, 1889, if there has been any important rise in the river-bed resulting therefrom, it should show itself in a corresponding rise in the extreme low-water surface. Several places will be considered, selecting those where our gauge records cover as many years as possible.

(1) *Cairo.*—The lowest water record extends back to 1859, with breaks, but is continuous since 1871. January 1, 1888, the gauge read 1.8 feet, and October 22, 1889, it read 2.7 feet. From November 10, 1859, to these dates the record gives but three dates when the water was as low as in 1888 and 1889. These dates were:

	Feet.
December 26, 1871 (Cairo gauge)	1.0
December 6, 1872 (Cairo gauge)	1.0
January 1, 1877 (Cairo gauge)	1.0

These gauge-readings are lower than those of 1888 and 1889, but the period since 1880 is entirely too short to conclude that in it there was a year in which the discharge reached its lowest value, thus giving extreme low water. The greater low-water heights in 1888 and 1889 may be simply due to there being more water flowing in the river at those times than in 1871. If in seventeen years following 1888 there are no gauge readings as low as those of 1871, 1872, and 1877, it will in some degree indicate, but not prove, that the bed has risen. At present the data do not extend over a period long enough to draw any reliable conclusions.

(2) *Memphis.*—This gauge read:

	Feet.
November 20, 1887	1.20
January 4, 1888	0.80
October 26, 1889	1.90

The records of low water before these dates extend back to 1848, and are continuous back to 1871. The records back to 1848 give but three dates when the water was lower than on January 4, 1888, namely 0.80 foot. These dates are:

	Feet.
December 29, 1871	−0.92
December 25, 1872	−0.95
January 2, 1877	+0.75

Here again the extremely low waters of 1871 and 1872 show themselves, and they are lower than any since 1880. But as was said with reference to Cairo, the period since 1880 is entirely too short to enable us to assume that in it there has been a year of minimum flow, or what amounts to the same thing, that there will not, in a few years, occur a stage as low as that of 1871.

(3) *Helena.*—The low-water record is continuous, excepting 1878 and 1879, back to 1871. The gauge read: December 29, 1871, 1.15 feet.

The record afterwards gives no waters as low as these till 1887. The gauge read:

	Feet.
November 20, 1887	1.20
January 4, 1888	0.80

Comparison of the two periods gives a difference too small to establish a rise of low-water level.

(4) *Lake Providence.*—The low-water record extends back to 1872, and the lowest waters are:

	Feet.
December 29, 1872	−3.85
October 16, 1879	+0.55

Since 1880 the two lowest waters are:

	Feet.
November 22, 1887	1.52
October 31, 1889	2.80

There seems to have been a great depression of low water in this part of the river about 1872. The Terrapin Neck Cut-off, shortening the river about 16 miles, occurred in 1866, and may have been a partial cause. The gauge-readings given indicate a rise in the water surface, and probably of the bed, at Lake Providence since 1872.

(5) *Vicksburg.*—Excepting 1878 and 1879, the low-water record is continuous back to 1872. The gauge read: December 30, 1872, —1.30 feet.

From this date to 1886, the lowest record is: January 6, 1877, 2.25 feet.

Since 1880 we have:

	Feet.
November 16, 1886	0.00
November 24, 1887	—3.91
January 7, 1888	—1.32
October 29, 1889	—0.80

Here the gauge records indicate a fall in the low-water surface, and perhaps a fall in the bed. The question is complicated by the Terrapin Neck Cut-off of 1866 and the Vicksburg Cut-off of 1876.

From 1872 to 1881 the low-water fall in the surface of the river between Lake Providence and Vicksburg varied between 21 feet and 22.9 feet; in 1883 it was 24.9; in 1886, 26.2; in 1887, 29.0; in 1888, 26.7, and in 1889, 27.2 feet. The change of fall from 22.6 feet in 1877 to 29.0 feet in 1887, amounting to 6.4 feet, is very great. About two-thirds appear to be due to a sinking of the low-water plane at Vicksburg, and the rest to a rise in the low-water plane at Lake Providence. The low-water slope from Lake Providence to Vicksburg was in 1884 still much greater than just above or below. Its great value was probably due to the two cut-offs. In 1884 the distance from Lake Providence to Vicksburg was 57 miles; the sum of the two cut-offs was 18 miles. If we suppose that before these two cut-offs the river was two-thirds of this 18 miles longer than now, or the distance from Lake Providence to Vicksburg to have been 69 miles, the slope would have been but fifty-seven-sixty-ninths of its present value. The result of the cut-offs would be to increase the velocity of the river above and near them. This increase of velocity would tend to scour the bed and banks, perhaps making a deposit in the river below the cut-offs and temporarily raising the bed there; and it may be that it is now returning to its normal low-water position by removing the deposits below.

(6) *Red River Landing.*—The low-water record is continuous back to 1872, which was the year of the lowest known low water, the gauge reading 0.0 In 1879 it fell as low as 0.55, and in 1887 to 0.47. The difference in low-water heights of 1872 and 1887 is too small to be evidence of a rise in the bed of the river.

Thus far only low waters of the Mississippi have been considered. The high-water records cover longer periods, but as an increased high water may result from confining the floods between levees as well as from a rise of the bed of the river, it can not be concluded from a rise of flood-heights in the river that the bed has also risen. At Cairo the gauge read:

	Feet.
June 21, 1858	49.6
May 2, 1862	50.8
March 21, 1867	51.0

The river did not again reach these heights till February 26, 1882, 51.87; February 27, 1883, 52.17.

This increase in the later heights is not supposed to indicate any rise of bed, but can be accounted for solely by a greater flood discharge.

At Memphis the record goes back to 1828. In 1862 the river reached a flood height of 34.45, the record then showing no greater one. In 1882 the greatest height was 35.15; in 1887, 35.30, and in 1890, 35.60. This rise of 1.1 feet since 1862 may be accounted for by a greater discharge by the construction of levees below Memphis and perhaps by the influence of railroads across the St. Francis bottom, without the supposition of a rise of bed.

At Vicksburg the record goes back to 1823. The highest known water was 51.1 feet in 1862. The next highest was 49.1, March 15, 1890. Here there is no indication of a rise of bed.

At Natchez the record goes back to 1802. The highest water was 49.9 in 1862. In 1890 the highest water was 48.6 on March 22. In 1815 the highest water was 48.5. There is no indication of a rise of bed.

From the examination of the Po and Rhine it may be concluded that if their beds rise in the leveed portions (which is not entirely certain from the data), it is at so slow a rate as not to be an important factor in the maintenance of a levee system. With levees 10 feet high, if the bed rose at the rate of 1 foot in a hundred years, the cost of raising a line of levees having the length of the present Mississippi system—about 1,300 miles—by this one foot would be but about $4,000,000, distributed over

the country, or $40,000 per annum, which is a small part of the annual cost of the system. On the Mississippi the records, while not extending over a period long enough to give final results, do not, so far as they go, indicate that the bed has risen.

The opinion so often held that levees cause a river-bed to rise is probably due to the fact that the bed of a river does sometimes rise although leveed, and hence it is concluded that the levees cause the rise. Any sedimentary stream, having a definite succession of stages and discharges and flowing in its own alluvion, finally takes such a slope as will give a velocity sufficient to enable it to carry its sediment, whether derived from above or from its own banks and bed, farther down-stream, without, on the whole, scouring or filling its bed. An average velocity less than this will give rise to deposits in its bed, or if it is crooked it will become straight, thus in either case increasing its slope and velocity towards their normal values. An average velocity greater than this will scour its bed, or cause caving in its concave bends, thus increasing its length and diminishing its slope and velocity to such values as its bed can bear without on the whole scouring or filling. When therefore the slope of a sedimentary stream suddenly diminishes from that which it needs for a stable regimen its velocity also diminishes; it drops part of its alluvion, and its bed rises. Thus, when the Mississippi enters the Gulf of Mexico, its slope suddenly diminishes; its velocity diminishes, and it builds up bars out in deep water. So the Adige, where it reaches the low plains of the Po, needs for permanence a steeper slope than the country has, and raises its bed above it. In all these cases the bed would rise without levees.

There is one more cause for the rise of bed of a sedimentary river, which, however, acts at a very slow rate. The Mississippi pushes its mouths out into the Gulf at the rate of about 4 miles in a century, and this increase in length requires a corresponding increase in fall of water surface to make the waters flow out. An increase of 4 miles in length would, with existing slopes, raise the high-water surface at New Orleans about seven-tenths of a foot. The cost of raising levees to correspond with this rise in the water surface would, as has already been seen, be a small part of the annual cost of the system.

C. B. COMSTOCK,
Colonel of Engineers, Bvt. Brig. Gen., U. S. A.,
President Miss. River Commission.

NEW YORK, *May* 10, 1890.

Levees on the Hwang-Ho.—The following information, taken from the North China Herald, has been transmitted by the Hon. Charles Denby, United States minister at Peking, to the Secretary of State, and by him to the Mississippi River Commission.

In reference to Mr. Morrison's statement that the bed of the Hwang-Ho is in places higher than the surrounding country, it does not appear that he made measurements except at the break in the levee. There he states that the river was almost at its lowest and that the old river was practically dry. But as the old river below the break may have shoaled up since the break, it does not by any means follow that prior to the break the river was above the surrounding country. The fact that he found below the break on the main river the extraordinary slope of 1 foot per mile also points to a local shoaling immediately below the break, which may have occurred since the break.

C. B. C.

NEW YORK, *May* 16, 1890.

THE YELLOW RIVER.

A meeting of members of the Shanghai Literary and Debating Society was held yesterday evening at the Philharmonic Hall for the purpose of hearing Mr. G. J. Morrison, M. Inst. C. E., read a paper giving an account of a visit to the breach in the embankment of the Yellow River near Chengchow, in September, 1888.

During the summer of 1888 the foreign residents in China were much interested in the accounts received from time to time of the effects of the great breach which had occurred during the previous autumn in the bank of the Yellow River and in the works undertaken to close it. These accounts, however, were of a most conflicting character, both as regards the amount of damage done by the flood-water and the progress of the repairs. At one time it was confidently stated that the works had almost reached a successful termination, at another time that work to the value of some tls.10,000,000 had been entirely washed away, and at another time that very little real work had ever been executed, and that the stories of disasters were invented with a view to conceal the malversations of officials of various ranks.

Along with these reports there appeared from time to time proposals for closing the breach, for keeping the breach open, and conserving the river in its new bed, and for

conserving the river generally. Whatever merit there was in any of these schemes was counterbalanced by the fact that few of them were founded on personal observation by competent persons, and while some of them undoubtedly contained valuable suggestions, they were of such a crude nature that the officials at the breach could easily show that if adopted in the proposed form they would certainly result in failure, and the Chinese Government adopted none of them.

Interviews with H. E. Li Hung-Chang, however, and with other high officials, made it quite clear that an appalling calamity had occurred, that the attempts to repair the damage had been unsuccessful, and that from a state of certainty as to their ability to rebuild the embankment the officials had passed to one of hopes of success, and had finally arrived at a condition where fear of eventual failure was uppermost in the minds of those best able to judge.

Under these circumstances some of the residents in Shanghai began to think it might be worth while to have some definite information as to the state of affairs, and I was commissioned by the Hong-Kong and Shanghai Bank and Messrs. Jardine, Matheson & Co. to visit the breach and report on what I saw.

H. E. Li Hung-Chang expressed himself as being most favorably disposed to my visit, and while not acting on his behalf, I had the advantage of a special passport and a letter requesting the local authorities to give me all the information and assistance in their power.

It was arranged that I should be accompanied by Mr. G. A. Hillier, of the Hong-Kong and Shanghai Bank, and starting from Tientsin on September 14, 1888, we arrived at the breach on the 27th, after fourteen days' continuous cart-traveling from daylight till dark.

Before saying anything regarding the breach it will be convenient to make a few remarks on the Yellow River generally.

All residents on the coast of the northern portion of China are acquainted with the way in which the land gradually extends seaward. The immense amount of silt brought down by the Yangtze, the Yellow River, the Peiho, etc., and other less important streams is deposited near their mouths. As this land grows, the inhabitants gradually bring it under cultivation. Being very low, it is constantly exposed to floods, and one of the first works of the farmer is to build a small embankment along the most exposed places. The streams, being subject to floods from inland waters, rise higher than the tides, and embankments along these become of vital importance. As the extension of land proceeds population increases, and possession is taken of the ground on the river side of these embankments, outer embankments being constructed so as to protect this newly reclaimed land from floods, and this work goes on on both sides of the river until the channel is contained between two embankments only sufficiently far apart to allow the water to pass in times of flood; any attempt to encroach further on the river being sure to end in failure.

I do not for a moment maintain that the Yellow River has deposited the great plain of China during the life-time of the human race, nor do I even wish to raise the question of the origin of the main portion of the great plain at all, but what I wish to make clear is that ages ago the population found a river divided probably into several streams, that they gradually built embankments one after another to protect their fields against floods, until at last they confined this immense river between two more or less substantial embankments, and that it is with this river thus artificially controlled that we have to deal, and not a river wholly or even in great part existing under natural conditions. One of the first effects of such embankments is to raise the level of the high floods. An amount of water which will flood an area 50 miles wide 2 feet deep is sufficient to flood a width of 5 miles 20 feet deep; and though no such simple proportion exists in reality, still it must be clear that as soon as the width of the flood channel is decreased the depth of the floods increases, and the final embankments must therefore be much higher than the first protecting banks.

Between these embankments thus the river flows usually in a comparatively narrow channel, but in times of flood it extends to the embankments, rises above the level of the surrounding country, and when it finds a weak spot breaks through and floods the adjacent lands. It was a calamity of this sort which occurred last year in Shantung, but, under the conditions referred to above, such an inundation, however appalling, can be only temporary. In a few weeks or months, as the case may be, the river falls, the flood waters drain off, and the embankment can be repaired. It may be and often is worth while to try to stop breaches of this sort even before the subsidence of the flood, but it must be clear that the closing of such a breach need never baffle human ingenuity. The time is sure to come when the work will be simply that of making a river embankment.

As time goes on, however, quite another state of affairs comes into existence. If the embankments are kept intact each flood leaves a certain amount of deposit. This is most marked near the embankments where the water is shallow and the speed of the current less than in the center, but it tells by degrees even on the low-water channel itself; and after a time it is no longer the surface of the flood-water

that is higher than the surrounding country, but the very bottom of the low-water channel becomes higher than the land outside the banks. How long it takes for this state of affairs to be brought about I do not pretend to say without much more information than is possessed at present, but this may be safely stated, that all raising of the bottom of the low-water channel above the general level of the country has taken place since the river was confined between artificial embankments. Of the extent to which this raising has taken place I shall speak further on, but it does exist along a considerable portion of the present bed and of the old bed which it occupied until about forty years ago, and which now goes by the name of Yu Huang Ho or Silted Yellow River, showing that the Chinese are well aware of the fact.

Under such conditions as these a breach of the embankment resembles such a breach as I have before described, in name only. No matter how low the water may fall it will continue to pour out of the bed into the country; and when it is remembered that the Yellow River is one of the great rivers of the world it is seen that the closing of such a breach is beset with difficulties such as have rarely if ever to be encountered during the execution of the most extensive engineering works of modern times.

In the maps which many of us used at school, the Yellow River was shown (and correctly shown) as entering the Yellow Sea south of the province of Shantung, crossing the Grand Canal at a place called Chingkiangpoo (not to be confounded with Chinkiang on the Yantze). Early in the fifties, however, it was noticed that the color of the Yellow Sea had considerably altered, and I believe it was Dr. Macgowan who first brought to the notice of residents here the fact that there was abundance of evidence that the river had changed its course and was now flowing into the Gulf of Pechili.

In 1868 Mr. Ney Elias visited the river and made a map of the new course, from which it appears that at a place called Lungmênkow, some 10 miles east of Kaifongfu, the river had burst through its northern embankment and, flooding the adjacent country, had eventually found its way to a small stream called the Tatsing and had taken possession of its bed, carrying away bridges and other obstructions, and, passing a few miles west of Tsinanfu, the capital of Shantung, was flowing into the Gulf of Pechili at a place named Tiehmênkow. In its course it crossed the Grand Canal at a place called Pahlimiao and at the time of Mr. Ney Elias's visit the portion of the river between the breach and the canal was in a deplorable condition. Any attempts that may have been made to close the breach must have entirely failed, and between the points above mentioned a tract of country some 20 miles wide was practically given up to the river. Below Pahlimiao the river, following a bed below the level of the country, was well defined.

When I visited this place in 1878 great changes had been effected in the upper portion. Close to the breach, it is true, the scene was still one of the utmost desolation. The river consisted of a net work of channels where deep holes were followed by shallows of such slight depths that my boat, drawing a little more than a foot of water was often aground, on two or three occasions for hours at a time, while the banks of the river were unrecognizable and probably really out of sight. After about twenty miles, however, there was a great change for the better; the officials had been at work, and the immense marsh intersected by channels of various sizes had given way to a river confined to one low-water channel, and with embankments along both sides at a moderate distance, apparently just sufficiently wide apart to take the flood waters.

Below Pahlimiao as far as Tsinanfu the river was in precisely the same condition as at the time of Mr. Ney Elias's visit. Of the lowest portion of all I cannot speak, as I have never seen it.

It appears, therefore, that as soon as the officials discovered that they could not close the breach they set about conserving the new channel. The portion between the canal and Tsinanfu presented no difficulties, but the upper portion was little but a marsh and had to be converted into a river by the construction of embankments, and, as giving some idea of the time occupied by such works, the length between the breach and the Grand Canal measuring about 100 miles had been nearly but not quite brought under control in some twenty-five years after the breach had occurred.

The whole of the new course from the great breach at Lungmênkow above referred to appears to be below the general level of the country immediately adjacent to the river, and there is therefore fair reason to suppose that, if moderate care be taken to protect the embankments, any floods arising from breaches along this part of the course will be for many years to come only temporary, and the river will stick to its present bed. In course of time, however, the process of silting will gradually raise the bed and the officials will go on raising the embankments. At last some day a breach will occur which the officials cannot cope with, and the present course will be left high and dry, and a new tract of country will be flooded, the officials will again control the river between embankments, and the silting will take place as usual and eventually bring about another catastrophe. These things have happened more than

once in historic times, villages still existing which derive their names from having been on the banks of the Yellow River, and the traveler in these districts very soon understands why the river has been called China's Sorrow.

The Yellow River appears to have a great fall as it flows through Shansi, its height above the sea at the northern point of Shansi being about 3,500 feet and at the southern point where it enters Honan probably not more than 500 feet. It consequently enters Honan charged with silt, and, its velocity being checked, immediately begins to deposit it. The heavier particles are deposited first and the silt found in the northwestern part of Honan, as evidenced by the bed of the river, by the remains of a channel formed after a breach about a century ago, and by the embankments which are made from the bed of the river, is pure sand, so clean that when a quantity is rubbed between the hands it leaves not the slightest stain. Further down, however, there is a more muddy deposit, and the old bed, which runs past Chingkiangpoo, is now cultivated and is exceedingly fertile. As most silt is brought down during floods the portions of the bed between the low-water channel and the embankments are quickly raised. The low-water channel alters its position from time to time and when it keeps for a long time cutting towards one embankment, the land which it leaves between it and the other embankment soon rises to nearly the level of the highest floods and is covered only at intervals of many years. This land is then brought under cultivation and a comparatively low embankment suffices to protect it against occasional floods. On the other side of the river, however, the safety of the embankment is soon threatened, the officials begin to strengthen and protect it and if at last they find the river too strong for them they build another embankment outside and let the old one go. In this way one often finds several embankments parallel to the river, but one which has been built in a silted bed is easily distinguished from an original embankment which separates the bed from the ordinary country. The former of these has the land on both sides approximately level; not so the latter, *i. e.*, the original bank. The appearance of the first of these banks which are seen by a traveler is most surprising. Going along through the country he sees something like a railway embankment 30 or 35 feet high. On reaching it he ascends and finds the top as a rule from 30 to 60 feet wide, but on looking down on the inside he finds the bed only 15 or 20 feet below him. He can hardly help thinking that the country is the bed and that the bed is the country, but he soon realizes the fact that when the embankment was constructed the land on both sides was probably about the same level, but years of silting had raised the bed far above the country. While, however, the general appearance, particularly in the case of the old and disused bed, leads one at first to think that the general level of it is from 12 to 20 feet above the country, measurements show that it is only at the edges that the bed is so high, and that the lowest portion of the bed is probably not more than 5 or 6 feet above the general level of the land outside.

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Having thus given a general description of the Yellow River, I may proceed to give some details of the great breach of 1887. The town of Chengchow, near which it occurred, lies some 40 miles west of Kaifongfu, and the river at this point flows in its old bed, the great breach of 1854 having occurred some 50 miles lower down. The embankments here are constructed of little but sand, and the river has for many years been cutting away its southern shore, the northern embankment having been left many miles to the north. The low-water channel runs for a long distance close to the southern embankment, while its bottom is 4 or 5 feet above the level of the country outside. In the autumn of 1887 the appearance of the river became very threatening, and despite the utmost efforts of the officials to protect the embankment against the effects of the current, it was gradually eaten into. Towards the end of September water began to trickle through in several places, and on the 29th of September, 1887, a portion of the embankment gave way.

As soon as the water began to run through the opening the embankment was quickly carried off by the flood, and in a very short time no less than a mile of it had entirely disappeared. Through this gigantic opening the entire river flowed out quickly, eating down its own bed close to the gap to the level of the country outside, and before very long the old bed of the river below the gap was left perfectly dry.

The water which came through the gap, that is to say, the whole of the water of the Yellow River, flooded an immense track of country. There being no valleys along which water would naturally run, it seems to have spread itself over such a large area that there was very considerable difficulty in saying what was the direction of the main stream. Probably the principal portion of the water found its way towards the Hungtse Lake, the level of which was considerably raised. Thence a large portion flowed through the Kao Yao Lake and along the low-lying land bordering the Grand Canal to the Yangtze, while a considerable portion passed into the Grand Canal and was thence directed as far as possible through the numerous sluices in the eastern bank towards the Yellow Sea. The amount of damage done by this flood is not very well known. Numerous villages were swept away and some cities suffered

considerably, one having been saved only by the populace looting the pawn shops and filling up the gateways and other openings in the walls with clothes, and so protecting the interior from being ruined by the first rush of the torrent. Still, after the first news of the disaster, the subsequent reports were of a much less distressing nature than was expected. It is probably the case that the area flooded was so wide that the average depth did not exceed a very few feet, and as in even the flattest country there are differences of level of a foot or two, large portions of every district must have been left uncovered, while further portions could be reclaimed with scarcely any trouble. In this case the distress would rather be wide-spread than acute, and though the suggestion is not founded on direct evidence, there is good reason to believe that it nearly represents the actual state of affairs.

Under these circumstances there were two courses open to the Government. One was to close the breach and bring the river back to its old course, the other was to leave the breach untouched, to make a new channel for the Yellow River towards either the Yangtze or the Yellow Sea, leaving the old bed to be cultivated in certain portions, and probably to form lakes in other places. The idea that the river must have picked out the best course for itself may at once be dismissed. It has been flowing in a raised bed, that is to say under entirely artificial conditions, and had broken through at one point and flooded the country. It broke through not because the general lay of the country was favorable to it, but because the artificial bank happened to be weak at that point. There might be, and I believe there was, a very much better course on the north side of the old river, but the water having once dropped down on the southern side was prevented by the old artificial course from ever again finding its way north. While, however, there is no possible excuse for saying that the river had found the best course possible, it is true that if confined between embankments it would have been constrained to follow a course probably a few feet lower than the adjacent country, which would be a much better channel than the one it left; but then it must be remembered that the old high-level channel continued for only about 50 miles below the breach, viz, to Lungmênkow, where the old breach of 1854 occurred, below which point the river followed a channel at least as good as, and I believe considerably better than any that could be picked out for it to the south, and one on which moreover the officials had been at work with more or less activity for more than thirty-five years, and which in any case is better now than the new channel to the south could be made in thirty-five years more by the construction of some 800 miles of heavy embankments, to say nothing of the temporary works. I believe then that the Chinese officials were fully justified in determining to close the breach and restore the river to its course if they could.

The system which the Chinese authorities adopted of closing the breach was in one sense the simplest possible. Finding that a mile of their embankment had been cut away they started at each end of the old embankment and carried forward new ones to meet near the middle of the breach. The water as before stated had flooded all the country for miles in every direction outside the breach, but a small embankment of a few feet in height was run out from the western end of the breach approximately at right angles to the river and this protected the land to the westward, but all the land to the south and east remained flooded as far as the eye could reach, one of the principal streams running close along the outside of the eastern embankment with a depth of 10 or 12 feet.

It is evident that if the authorities had simply constructed their embankment of sand it would have been washed away as fast as they made it, and they therefore constructed it of bundles of millet stalks fastened together with ropes and stakes and filled in with mud, if they could get it, but generally with sand, and loaded with stone.

As before stated the old embankments are from 30 to 60 feet wide on top, but the officials rightly judged that such a width would be too small for their new bank, which they therefore built much wider, but most people will be surprised to hear that the width varied from 250 to 350 feet and the average was fully 300 feet. The stalks of the Kaoliang or large millet are neither strong nor lasting, and in most respects are much inferior to willows, or osiers, generally used in Europe, but they are yielding, and as each layer is weighted by the layer on top the mass is crushed together and the sand is retained so that the embankment becomes impervious to water; while if osiers are used the sand gets washed away and the embankment is little better than a sieve, and I soon became convinced that for the purpose in this special case no better material could be used. The means of obtaining materials and labor was simplicity itself. Notices were put up that millet stalks would be bought at the works at a certain price, which varied at different seasons, and I saw one proclamation stating that all delivered before a certain day would be paid for at the rate of Tls. 0. 0. 2 per catty, or say a half penny a pound, and I saw millet stalks being carried to the works in barrows; so the immense quantities required appear to have been collected in very small lots. As the millet stalks arrived they were tied in bundles and built in stacks. When required for the works the coolies went to the

stacks, each man received a bundle, and proceeded to the embankment, where, on passing through a wicket gate, he received a stated number of cash. As regards sand it appears that the men could go for it where they liked, and on bringing a barrow load to the works each man on passing a wicket received 30 cash if his barrow was considered full.

On this system work no doubt went on easily enough at first, but it will be readily understood that as the two ends approached each other the speed of the current increased, with the natural result that the bottom was eaten away. The lowering of the masses of millet stalks at the ends of the embankment became a work of some difficulty. The method adopted was generally as follows: A large boat was anchored near the end of the embankment and ropes were let down the embankment and laid over the boat. On these ropes masses of millet stalks were placed, the bundles being secured together by ropes and stakes filled in with stones and sand, and this mass was eventually lowered between the boat and the embankment, the ropes from the boat being eventually brought over the mass and fastened back to the end of the bank by stakes. When a certain number of these masses had been laid so as to come above water-level, the whole was built up as high above water as was thought necessary.

Probably ignorance of the almost superhuman exertions that would be required to construct the final length formed a great element in the enthusiasm of the officials, and they are perhaps hardly to be blamed if, when the original width of 5,300 feet had been reduced to 500 or 600, as must have been the case in the summer of 1888, they spoke of the completion of the work as being near at hand; but they were doomed to disappointment. The summer floods treated them very badly, not only by washing away some portions of their work, but by scouring out the breach to an almost incredible depth. It seems to have been about this time that the higher officials began to get alarmed. They began to realize the fact that the work before them was of a gigantic character. The amount of the embankment swept away was not very large compared with the whole work executed, but to replace it was far more difficult than the original work of construction. The current was gradually eating away below the new embankment and was threatening to undermine it entirely.

It is greatly to the credit of the local officials that they did not lose heart. They cast in immense quantities of stone brought from quarries about two days' sail up the river, and where portions of the embankment sunk they added fresh material on top, thus adding weight to the whole structure, and so preserved the bulk of their work until the falling of the water gave them breathing time.

When I arrived at the breach in September the ends of the two embankments were within 400 feet of each other, measured at the top. They were, as I have previously said, about 300 feet wide, and at the ends they were about 40 feet above water, this height being given partly in order to add weight to the lower portion and prevent its being carried away, and partly to facilitate the building of masses of fascines to lower into the water; but the great feature was the depth of water, which was 70 feet.

The speed of the current was not very great. Boats passed down from time to time, but seeing that the breach was full of eddies of such extent that sometimes boats were carried right up on the west side, no proper measurement could be made. Judging from the appearance of the boats going down, I estimated the velocity at seven miles an hour.

Practically the whole of the work up to this point had been done by Li Hung-tsao, who had been long in charge, but had just been sent for to Peking, and who had been replaced by Wu Ta-chêng, who took charge a short time before my arrival.

The bed of the river below the breach was practically dry. A small canal had been cut along it to relieve the breach of some of the water, but it was so small and so poorly executed that for practical purposes it may be disregarded, and the level of the water flowing through the breach was distinctly lower than the old bed. Very careful leveling showed that the lowest part of the old bed just below the breach was 18 inches higher than the surface of the flood water outside the bank, and as the average depth of this was certainly over 2 feet 6 inches, the bottom of the river was at least 10 feet above the average level of the country, and as the depth in these places where the flood waters were flowing quickly was about 10 feet, or more, it may safely be said that the bottoms of the ordinary water courses in this district were some 12 feet lower than the bottom of the Yellow River.

Mr. Hillier had some long interviews with Wu Ta-chêng, who, from the first, expressed himself as being confident of success, but it is not surprising that many people took a less hopeful view. I found that all the European engineers who had expressed any opinion on the subject had stated their belief that the Chinese could never close the breach by simply advancing the two ends to meet, and those who had examined the place most carefully were most decided in their opinions.

On my arrival I at once proceeded to make a general survey of the place and to take some levels, and after I had by these means made myself acquainted with the leading facts of the case I began to consider more closely the possibility of the Chinese

being successful, and on the other hand to put into practical shape some scheme for closing the breach should the Chinese fail. The only fact of great importance which I have not already stated is that the fall of the bed of the river immediately below the breach is as nearly as possible one foot per mile. This is a very great fall for such a large river, but the result was arrived at by careful leveling, and is undoubtedly correct for a very considerable distance. This fact has an important bearing on the possibility of cutting a channel along the old bed so large and so deep as to draw away the water from the breach. It will be seen that the construction of such a channel would be possible, but would be a very large work, and the Chinese proposal to construct one 15 feet deep and 1 mile long under the impression that once the water was let into it it would rush down and carry everything before it, clearing out a channel for itself, seemed to me so utterly unpractical that I gave it no further thought and I turned my attention solely to the breach. It was clear that by simply crowding on men and employing materials in the most lavish manner the Chinese had constructed two immense and most substantial embankments, fully able to do their part of the work if the gap was closed, but the most important point was that the breach had been scoured by a most severe flood much greater than any that might be expected for several months. This flood must have undermined the ends of the embankments which sank and was made up on top, but which must have slipped out a considerable distance towards each other at the bottom. The water, when I saw it, was almost at its lowest, and would probably remain like that for three months; and it appeared to me that the gap might be considerably narrowed before the velocity became as high as it had been during summer, and till this occurred probably no further scouring would take place; and I thought it well within the bounds of possibility that fully 100 feet could be added to each embankment in somewhat the same manner as the first part had been made. By that time the tops of the embankments would be within 200 feet of each other, their bottoms would certainly touch, and it seemed possible that by making a regular network of ropes over the breach, a mass of millet stalks and sand could be made of such a size and of such strength that when lowered into the breach the current could not carry it away. If this were done the interstices could be filled up with smaller masses and eventually the breach could be closed. I therefore represented to H. E. Wu Ta-chêng and to H. E. Li Hung-chang that in my opinion they should strain every nerve to proceed with the work in the ordinary manner, and not until the next flood overpowered them should they think of European systems, and there was, as I put it, an even chance in my opinion that they would be successful. This opinion proved to be correct, and on the 20th of January, 1889, the breach was finally closed, the immense depth of water in which this was effected being evidenced by the fact that there is a lake immediately outside 50 feet deep.

That the Chinese did right in making up their minds to close the breach, if possible, I have not the slightest doubt. There are many places where the river embankments are very bad, notably in the neighborhood of the late breach, but there are hundreds of miles of fairly good embankments, or at least of embankments as good as any others that could be built along a new course during the next twenty or thirty years.

Some of the latest instructions which have been given regarding the mouth of the river show that the authorities are learning either from experience or from good advisers something of the right of way of dealing with such rivers. When the Chinese have in former years been troubled with floods in their rivers they have been too ready to cut extra channels to carry off the surplus water. This as a rule is the exact opposite of what should be done. The extra channel lowers the velocity, the river deposits more silt, the bed rises, and the level of the floods becomes higher than ever. The last instructions appear to be to close all the mouths of the river but one. This one the river must keep open, and its increased velocity will deepen the bed and probably lower the level of the flood-waters of the river.

I am by no means of opinion that the Chinese have mastered the science of river engineering, nor that even when good orders are given the work will always be carried out in a satisfactory manner; but I am perfectly certain that they can deal with the Yellow River better than any foreigner who has to base his opinion on the results of a cursory visit and such general information as he can pick up from notices scattered through books and periodicals, and if I hazard any opinion it will be to the effect that there is no radical cure for the troubles of the Yellow River. A board of conservancy might do much to keep the river works in such a state as to prevent the inundations that continually take place, but all hopes of inventing any scheme which will set matters to rights once for all is entirely chimerical.

In reply to a question as to what had been the result of closing the breach, Mr. Morrison said the river was now flowing in its bed.

The Rev. T. R. Stevenson, in moving a vote of thanks to the lecturer, said they had heard a most lucid explanation of one of the most interesting catastrophes of modern times.

The Rev. Dr. Edkins, in seconding, said: We are very much indebted to Mr. Morrison for the account he has given us of the Yellow River, and for his extremely graphic and interesting description of the breach and the way in which it has been closed up. It seems to me we see here what Chinese can do; and one principal reason why they are able to attack a problem is because of the great past behind them. It is not the first century in which they have undertaken great engineering works. It is very interesting to read in old Chinese literature of the way in which from time to time they have met the catastrophes of their rivers; and there is one especially interesting account in the history of the first century before Christ, in the reign of the Emperor Han Wu Ti, one of the great names of Chinese history. He visited the works himself. He was an eminent conquerer, and surrounded by nobles, statesmen, and men eminent in literature; and one interesting circumstance is that he himself wrote a poem which has been preserved ever since in Chinese literature, describing the breach and the work that was being done in filling it up. The point at which this took place is not very far from Chengchow, which the lecturer has himself visited. At that time China was a different country from what it is now. Instead of the kao-liang stalks, of which you have heard, they were able to collect considerable quantities of bamboos. Naturally this would render the work easier to accomplish, and would give greater power of resistance. There are many interesting circumstances which I will not attempt to enter into now, but I feel a very considerable gratification in thinking that the Chinese in maintaining their power of engineering to this extent show the effects of the history of the past upon them; and the knowledge and energy they are able now to exhibit is on account of the knowledge and energy which their forefathers acquired and exhibited before them. Considering the decided opinion that has been formed by the lecturer in regard to the success of the Chinese, and the decided approval he has given to the course they took to fill up the breach, I think we should have a great amount of satisfaction in the thought that the Chinese are not so incompetent as many men represent them to be, and that not only in river engineering, but in many other subjects that come before the statesmen of this country they are not so unprepared as many men suppose to meet their difficulties and turn their catastrophes into exhibitions of great energy. Upon the whole the result is that we should add something to our opinion in regard to the power and the competency of the Chinese to meet their difficulties.

APPENDIX B.

MEMORANDUM ON OUTLETS.

Outlets have often been proposed as a method of reducing flood heights on the Mississippi. The immediate results on flood heights are so evident and so beneficial when a large crevasse is formed, the good results of an opening far larger than ever occurs naturally seem so immediate and apparent, that it is not strange that many persons look on them as the true remedy for great floods.

In a letter of February 1, 1890, to the Chief of Engineers (extract appended hereto), I considered the effects of making an outlet a mile wide and to a depth of 10 feet below low water, from the Mississippi River into Lake Borgne, and need not repeat the discussion here. In it I assumed what is well known to all persons familiar with hydraulics, namely, that a sedimentary river flowing in its own alluvion only acquires a stable regimen when it has taken a slope suitable to its varying discharges and to the material through which it flows; and, as a rule, that these slopes diminish as the size of the river increases, and increase as the size of the river decreases. It may be well to give some examples of this general fact.

(*a*) The South Pass carried, in 1875, about one-fourth of the water that the Southwest Pass did. Its slope, from the head of the Passes to its original bar, was about one-third greater than that of the Southwest Pass.

(*b*) The observed discharges of the Atchafalaya in 1882 were from one-seventh to one-tenth of those of the Mississippi. Its average slope to the Gulf is double that of the Mississippi.

(*c*) The Salina Pass, in the Delta of the Danube, carries two twenty-sevenths of the total river flow, while the St. George Pass carries eight twenty-sevenths. The slope of the Salina is one-half greater than that of the St. George Pass.

These examples are sufficient to illustrate the general rule already stated, that sedimentary rivers flowing in their own alluvion take larger slopes the smaller they are. Hence, if at Lake Borgne or elsewhere in its Delta, the Mississippi were divided into two rivers, since each would be smaller than the present river, the two new rivers would go to work to obtain the new and steeper slopes suited to dimensions

smaller than those of the original river, and hence would build up their beds. This process would only cease when the steeper slopes needed by each were obtained. Since both rivers would then have one end at the gulf, and have steeper slopes up to their point of divergence than the main river now has, the flood surface of the river at that point would be higher than now.

There have been cases where the experiment of dividing rivers in two has been tried by nature or by man. About A. D. 1438, the Adige broke its levees and poured its waters south into the Castagnoro and Canale Bianco, which then formed a drainage stream parallel to the Po. In 1545 the break had so increased that two-thirds of the low-water flow of the Adige and three-fourths of the high-water flow went through it. A low dam was built across the Castagnoro, to check the flow into it, and both rivers raised their beds. In 1678 a new dam was built, as the old one was then buried in the deposit. The bed still rose. In 1791 a masonry dam 39 feet high, with many archways through it to allow floods to pass, was built across the Castagnoro. The bed continued to rise and the floods on the Adige were so high that in 1838 the Castagnoro was permanently closed. In the six years following the closure the floods in the Adige fell, and the more markedly the nearer the point considered was to the Castagnoro.

Thus far only outlets have been considered which are permanent rivers. For such outlets the effect in finally raising the flood surface of the main river will be the greater as the flow of the outlet is more nearly equal to the remaining flow in the main river. If the outlet is small its effect on the main river will be small.

Places at which there is no escape, except at high stages, are sometimes called outlets. For many years prior to the recent closing of the levee gaps along the Mississippi, below Red River, and of the gaps which permitted water to escape from the vicinity of Turnbulls Island into the Atchafalaya Basin, the maximum flood flow past New Orleans was but about 1,100,000 cubic feet per second. This flow is ample for all navigation purposes, and no practical gain to navigation will result from increasing it. In 1882 it was estimated that about 2,200,000 cubic feet per second passed the latitude of Red River mouth. It has been proposed to allow only 200,000 cubic feet per second to go down the Atchafalaya, leaving 1,900,000 or 2,000,000 cubic feet per second to go down the main river. In my judgment, until the heights of levees below Red River are largely increased, there should be left a free opportunity for the escape overland of 400,000 cubic feet per second from the vicinity of Turnbulls Island into the Atchafalaya Basin, in such floods as that of 1882, in addition to the 200,000 cubic feet per second which is to go down the Atchafalaya. If such an escape, existing only at high water, be called an outlet, then I think it necessary, at least for the present. It will do no harm to navigation, which was good enough for many years before the escape into the Atchafalaya Basin was reduced. On the other hand, to try to force, in a great flood, 1,900,000 cubic feet per second past New Orleans, with levees at present heights, is sure to renew the disasters to levees at or below Red River which have occurred this year. The injury resulting from many breaks below Red River is so much greater than that resulting from the escape into the Atchafalaya Basin, from the vicinity of Turnbulls Island, that the lesser interests should yield to the greater until it is possible to protect both.

It may be concluded that the reduction, by any large amount, of the flow of the Mississippi at Lake Borgne will be ultimately followed by a rise in the flood heights at that place and a shoaling of the river below and at its mouth.

Also, that until levees below Red River are much higher than they are now, about 600,000 cubic feet per second in the greatest floods should be allowed to go into the Atchafalaya Basin, thus relieving the river below.

C. B. COMSTOCK,
Colonel of Engineers, Bvt. Brig. Gen., U. S. A.,
President Mississippi River Commission.

NEW YORK, *May* 10, 1890.

[Extract from a letter to the Chief of Engineers, February 1, 1890.]

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The Lake Borgne Outlet.—A canal a mile in width leading from the Mississippi into Lake Borgne, its bottom being everywhere 10 feet below low water, as proposed by the bill, would, by an approximate computation, which is the only one practicable in such a case, divert from the Mississippi about 400,000 cubic feet per second when the stage of the river near Lake Borgne is about 7 feet above Gulf level, and 500,000 cubic feet when the stage there is about 9 feet. The corresponding stages at Carrollton would be about 10 and 12 feet (since the slope would at last be the present high-water slope), the maximum stage there being 15.6 feet above mean Gulf. An outlet diverting 400,000 cubic feet per second would lower the highest flood at Carrollton by about 6 feet. (These computations are based on the discharge curve at Carrollton of 1883.

If more water is forced past Carrollton hereafter by maintaining levees above, these figures will need modification.)

Judging from the effect of local changes of flood height elsewhere on the river, this lowering of flood height at Carrollton would die out in something like 200 miles in ascending the river. Since for this distance the slopes would be steepened, it follows that velocities would be increased, with their destructive effects on the banks of the river and on levees. The outlet would do no good to navigation, but rather the reverse. The first effect of taking 400,000 cubic feet per second out of the Mississippi would be a large lowering of the flood surface near the outlet. The flow through Lake Borgne would itself be a river of large size.

Both theory and experience show that when, at all stages, a reduction in the size of a river flowing in alluvial soil is made, or the river is split in two, the smaller rivers gradually take greater slopes than the main river had. Hence both the main river and the new river would gradually increase their slopes to suit the new conditions. Since the slope begins at the Gulf, it can not become greater on the main river below Lake Borgne, which is now nearly straight, without increasing flood heights at Lake Borgne. After some years, then, if both routes to the sea remained large rivers, the flood level above the outlet would be higher than it is now, unless, as indeed is not improbable, the large amount of sediment which would be dropped into Lake Borgne (where the flood velocities would at first be but about one-sixth of those in the Mississippi) should close this outlet, thus repairing the injury done to the main river. A large diversion of flow from the Mississippi to Lake Borgne would also seriously diminish the depths at the present mouths of the river.

For the following reasons, then, no important outlet at Lake Borgne should be either undertaken or permitted:

(1) It would for some years lower the floods at the outlet, accelerate velocities above it, and increase caving and the consequent destruction of levees.

(2) It would cause shoaling at the present mouths of the river.

(3) If both the new outlet and the main river below it remained important streams—that is, if neither of them closed itself under the action of natural causes—the flood heights at Lake Borgne and New Orleans would after some years be greater than they are now.

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APPENDIX C.

NOTE ON FLOOD REPORT FOR 1890.

The reports of the district officers on the flood of 1890 contain a large amount of valuable information. Two of them, those of Captains Kingman and Leach, contain some conclusions which have a very important bearing on the heights needed for levees. If the conclusions are not justified they should not pass without notice.

(1) Captain Kingman takes the discharge of the Nita Crevasse on May 7, 1890, as 402,000 cubic feet per second, and says:

"At that time it became equal to one-third the entire discharge of the river. Notwithstanding this enormous escape, however, through the outlet, the actual fall directly traceable to this crevasse of the gauge at College Point from its highest point was only about 1.9 feet."

This conclusion is largely in error, as will now be shown. It is necessary, however, first to say that errors of 5 per cent. are common in the gaugings of the main river when carefully and deliberately made, and hence that conclusions based on them are only approximate. In the gauging of crevasses, where the motion of the water is very irregular on account of the variations in cross-section of the crevasse channel, and where the observations are made hurriedly and under the danger of the observer's boat being carried into the crevasse by the high velocity, far greater errors must be expected, possibly amounting to one-third of the measured discharge. Whenever possible they should be checked by other determinations.

In attempting to determine the effect of a crevasse with a given discharge in lowering the water surface from the position it would have were there no crevasse, the simplest case would be that in which, at some gauge far enough above the crevasse not to be affected by it, the river height remained stationary during the whole time considered. In that case the whole lowering of the surface at the crevasse could be attributed to the crevasse. Should the river, however, be rising at the upper station this must be allowed for in estimating the effect of the crevasse. Should the river rise fast enough at the upper station to more than balance the increase of escape at the crevasse then the river surface might even rise at the crevasse, thus apparently showing a rise as the result of a crevasse, although the real effect is of course a fall

from what the water-surface would have been without the crevasse. Apparently overlooking this Captain Kingman's results are unreliable.

The observed discharge of the Nita Crevasse on March 23, 1890, was 89,000 cubic feet per second. On May 8, 1890, it was 402,000 cubic feet per second. The break occurred on March 14. Assume, in the absence of other information, that between these dates the discharge varied directly as the time, and interpolate for intermediate dates accordingly. An examination of the curves of water heights for stations above the crevasse will show that, while the crevasse affected river heights above as far as Bayou Sara, it affected the Red River Landing gauge height slightly or not at all. The Red River Landing gauge will then be taken for comparison with the College Point gauge to determine the effect of the crevasse on the water-surface at College Point.

From March 16 to March 31 the Red River Landing gauge was practically stationary, varying but 0.2 feet. In this time the College Point gauge fell 1.5 feet, and this fall was mainly due to the Nita crevasse, the Lafourche discharge changing very little. By interpolating as mentioned above, the discharge of the Nita crevasse on March 31 is found to be 141,000 cubic feet per second, which caused the lowering of 1.5 feet. From March 31 to April 21 the Red River Landing gauge rose 3.4 feet, nearly to its maximum, and then began to fall in consequence of the breaks below between April 21 and 23. Without crevasses this rise of 3.4 feet at Red River Landing would have given a rise at College Point, between April 1 and April 22, of about 1.8 feet. But the College Point gauge reading, instead of increasing by this amount, decreased by 0.1 foot; so that, as the Nita crevasse and the Bayou Lafourche were the only escapes during this time, and as the total escape at Bayou Lafourche was but about 40,000 cubic feet, the change in its escape (being that due to a change of gauge reading of but about a foot) was also small, and the reduction between April 1 and April 21 of the reading of the College Point gauge by 1.9 feet below what it would have been if the Nita discharge had remained the same as on March 31 was due almost entirely to the increase of the Nita discharge. Interpolating as before, for the discharge on April 21 we obtain 286,000 cubic feet per second, an increase of 145,000 cubic feet over that found for March 31. The fall at the College Point gauge of 1.9 feet, between March 31 and April 21, below its reading if the escape had not increased, is due to this increase of 145,000 cubic feet per second in the escape.

Hence, summing the effects of the Nita crevasse, it lowered the water surface from what it would otherwise have been:

	Feet.
Between March 16 and March 31	1.5
Between March 31 and April 21	1.9
In all, up to April 21	3.4

the escape on April 21, which caused this lowering, being 286,000 cubic feet per second. This result differs very widely from Captain Kingman's estimate of a lowering of 1.9 feet by an escape of 402,000 cubic feet per second.

As the maximum gauge reading at College Point, 5 miles below the Nita crevasse, was reached on April 22, the discharge of the crevasse doubtless increased after this date, and gave rise to a lowering of the water surface which, to obtain the full amount, must be added to the 3.4 feet already obtained. But several other breaks occurred from April 21 to April 23, between Red River and College Point, and the further effect of the Nita crevasse in lowering the water surface at College Point after April 22 can not be separated from that of the other breaks.

A lowering of water surface of 3.4 by an escape of 286,000 cubic feet per second would correspond to a lowering of 1 foot by an escape of 84,000 cubic feet; but, owing to the uncertainties in crevasse measurements, this can only be considered as an approximation to the truth.

(2) Captain Leach, from discharge measurements given in his report, concludes first, that the maximum discharge over the parallel of Memphis, in the flood of 1890, was 1,835,000 cubic feet per second, and that in 1882 it was 1,799,000 cubic feet per second, and hence that the maximum flow past the latitude of Memphis was greater in 1890 than in 1882 by 36,000 cubic feet, while it was less at Helena in 1890 than in 1882 by 231,000 cubic feet—a change in the difference of flow of 267,000 cubic feet per second; second, he attributes this change to the fact that in 1890 the whole flow at Helena was confined between levees; hence he conditionally concludes, third, that the maximum discharge of a given flood, when confined by levees, will be "but little greater than the maximum discharge in the channel of the same flood unrestrained," that is, not confined by levees.

These conclusions have so direct and important a bearing on the height needed for levees, and make the levee question one so simple that, if true, the plan of the Commission should at once conform to them. If not true, they are very misleading. The conclusions will be examined in order.

(1) The following table shows the relation of the flood height of 1890 to those of 1882 and 1883, respectively, from Memphis to Cairo:

	1890, above.		1890, below.	
	1882.	1883.	1882.	1883.
	Feet.	*Feet.*	*Feet.*	*Feet.*
Memphis	0.4	0.8	.....	.....
Fulton	.....	.....	1.8	1.4
Cottonwood	.....	.....	1.2	1.6
New Madrid	.....	.....	3.1	3.3
Cairo	.....	.....	3.0	3.3

It is seen, then, that from a point not far above Memphis to Cairo the flood of 1890 was below that of 1882 by amounts increasing to about 1.8 feet at Fulton and 3 feet at Cairo, and that these quantities are generally a little greater for the flood of 1883. With a flood so much lower along this principal part of the escape front of the St. Francis, a much smaller maximum escape than those of 1882 and 1883 must be expected and must have occurred. But that of 1882 was estimated by Mr. Stewart at 611,000 cubic feet per second, and that of 1883 at 413,000 cubic feet per second, by Mr. Johnson. The observations under Captain Leach give for the water crossing the railroads west and southwest of Memphis, in 1890, quantities varying from 484,000 to 579,000 cubic feet per second, or about the same as in 1882 and 1883, although the river above was so much lower.

Observations on escape over banks and through crevasses, and on flow over railroads and through railroad trestles, are exposed to a much larger percentage of error than those on the regular discharge of a river; even the latter are subject to considerable errors. Referring to the discharges at Memphis, given in Captain Leach's report, it will be seen that on March 31, 1890, the observed discharge was 1 313,000 cubic feet per second, and that on April 1, with the gauge 0.08 foot higher, the discharge was observed as 1,205,000 cubic feet per second, the latter being 108,000, or 8 per cent. less, with very little probability of any such change in the actual river flow. Observations along a railroad may easily have several times this percentage of error.

Captain Leach estimates the maximum flow in 1890, over the latitude of Memphis, as 423,000 cubic feet more than the maximum flow over the latitude of New Madrid. It is difficult to see where this enormous increase could come from. He also etimates the maximum flow across the parallel of Helena, in 1890, at 218,000 cubic feet per second less than that across the parallel of Memphis. It is equally difficult to see what could cause this diminution.

There is a method of obtaining the maximum swamp flow across the latitude of Memphis, in 1890, other than that of measuring the flow across railroads, namely, to subtract from the maximum flow across the parallel of Helena the flow in the river proper at Memphis one day before. The measures of the flow across the Kansas City, Springfield and Memphis Railway between March 17 and 19, and again between March 28 and 29, give nearly equal values to this flow. As during this period there was little variation in the gauge readings from Memphis to New Madrid, the swamp flow appears to have been a nearly steady stream, even if the observed values of its flow were too large. On March 29, having been a stream with steady discharge at Memphis for ten days, it must have had about the same steady discharge at Helena. The date of the maximum return flow at Helena is indicated closely by the date of maximum gauge reading there on March 28. The average Memphis discharges in the river proper from March 29 to April 1 are but 45,000 cubic feet less than those from March 17 to March 20; that is, the Memphis discharge from March 17 to April 1 varied but little; hence the maximum flow across the latitude of Memphis would be but two or three days before that at Helena. On April 3 the first discharge at Helena was measured as 1,547,000 cubic feet per second. The river had then fallen 0.4 foot from its maximum gauge reading of March 28. The discharge curve of 1882 at Helena gave higher discharges for like gauge readings immediately after the maximum than before, so we may take this 1,549,000 cubic feet per second for the Helena discharge on March 28, 1890. This discharge was the result of two streams. One of them passed Memphis March 27, in the main river, and was observed as 1,263,000 cubic feet per second; the water in the other passed Memphis, in the St. Francis bottoms, as a nearly steady stream on March 25 and 26. As this stream had been nearly steady opposite Memphis since March 18, it must by March 28 have become nearly steady, with the same discharge at Helena, only 50 miles below in a direct line. Subtracting 1,263,000 from 1,547,000, the difference, 284,000 cubic feet, should be the value of the swamp flow opposite Memphis at the time of its maximum

on March 26, 1890. It differs widely from the 484,000 cubic feet per second observed as the flow across the railroad. This wide difference in results obtained by methods which are both good is only another indication of the uncertainties which are large in measurements of the main river and still greater in those of escapes or swamp flows.

In this discussion thus far I have considered chiefly the flows down the valley at Memphis and Helena in 1890, in order to avoid the large uncertainties in the escape measures of 1882. Captain Leach has rather compared the flood of 1882 with that of 1890, finding a relative change in flow between Memphis and Helena of 267,000 cubic feet. But as this value is obtained on the supposition that in 1890 the total maximum flow past Helena was 218,000 cubic feet per second less than that past Memphis; if the last figures are unreliable the first are also. Captain Leach's estimate that the maximum total flow past Memphis in 1890 was 1,835,000 cubic feet per second is for the date March 17; if the date March 31 had been used, his result would have been reduced by only 23,000 cubic feet. Hence the difference between his results and mine does not in any great degree arise from my taking March 26, instead of March 17, for the date of the maximum flow across the latitude of Memphis.

The acceptance of Captain Leach's results requires us to accept as true the following statements: (1) Although, above Fulton, the river was from 1 to 3 feet lower in 1890 than in 1882 and 1883, yet the escape into the St. Francis Bottom was about the same. (2) The maximum flow down the valley, including the flow in the St. Francis Bottom, in 1890, increased from about 1,412,000 cubic feet per second at New Madrid to 1,835,000 at Memphis, an increase of 423,000, and then diminished to 1,617,000 at Helena, a diminution of 218,000. (3) For the diminution between Memphis and Helena, the theory is advanced that levees were the cause. The increase of 423,000 cubic feet between New Madrid and Memphis is left unexplained by this theory, as the levees there both in 1890 and in 1882 were practically open.

In view of the improbability that these assumptions are true, it only remains to attribute the results obtained by Captain Leach to errors arising from the uncertainties in measurement of discharge over and through many miles of railroad, and to errors in measuring the discharge of the river proper. It seems more probable, on the whole, that the total flow across the parallel of Memphis in 1890 was about the same as that across the parallel of Helena, and that it was, as at New Madrid and Helena, about 200,000 cubic feet per second less than in 1882.

(2) Captain Leach's conditional conclusion that the maximum discharge of a given flood, when confined, will be "but little greater than the maximum discharge, in the channel, of the same flood unrestrained," depends on the opinion that the maximum flood across the latitude of Helena, in 1890, was less than that across the latitude of Memphis by 218,000 cubic feet. As the premise is not established the conclusion is not proved.

The opinion seems to underlie this conclusion, that in some unknown way a great flood can be confined and carried down the river when it is so leveed as to prevent any escape, with little increase in the maximum discharge over that of the river proper without levees. The inaccuracy of such an opinion can be shown by referring to the flood of 1882. At Columbus, from February 22 till March 3, 1882, or for ten days, the discharge varied from 1,603,000 to 1,518,000 cubic feet per second, or in round numbers exceeded 1,500,000 cubic feet per second. Now suppose that this flow had been steady for the period at 1,500,000 at Cairo, and that there had been levees so high as to contain this discharge, and to keep out all water from tributaries as far down as Hays' Landing, 553 miles from Cairo. On February 22, 1882, the Hays' Landing gauge was 1.4 feet below its maximum for that year, and the discharge was 952,000 cubic feet per second. When the Mississippi River has no escape over banks and no change in flow of tributaries, it is well known that flood waves travel down it at the rate of about 80 miles a day, this rate including any delay due to the reservoir effect of the main river. With high levees there would be no escape. Taking this rate seven days after February 22, the flood-wave from Cairo would reach Hays' Landing, and the river surface there would cease to rise The flow being supposed steady at Cairo at 1,500,000 cubic feet per second, during this time the river surface, confined by levees, in any intermediate stretch could only cease to rise when the flow in at its upper end equalled the flow out at its lower end. Of the ten days, then, at Cairo, during which there was a steady flow of 1,500,000 cubic feet per second, only seven days would be needed to give the same steady flow of 1,500,000 cubic feet per second at all points on the river as far down as Hays' Landing.

It may be objected that sufficient account has not been taken of the reservoir effect of the river proper. This can be estimated approximately. Assume that the confined flow of 1,500,000 cubic feet would gradually increase flood heights in descending the river, so as to amount to 6 feet at Hays' Landing, or that the reservoir would have an average height of 3 feet for 553 miles, and assume that the levees are on the banks of the river and on an average one mile apart. The flow being 1,500,000 cubic feet per second at Cairo, and at maximum about 1,000,000 at Hays' Landing, the res-

ervoir is being filled at the rate of about 500,000 cubic feet per second, and at this rate a single day's flow would fill it. Add this day to the seven and there results in all eight days from February 22 before the constant flow of 1,500,000 cubic feet would be established between the high levees at all points between Cairo and Hays' Landing, and this steady flow would then continue on March 2 and 3, at the same value. Now the actual maximum discharge observed at Hays' Landing in 1882 was 1,019,000 cubic feet per second, and a steady flow of 1,500,000 from Cairo to Hays' Landing would have increased the maximum discharge at Hays' Landing by nearly 50 per cent., which is not "a little greater," but is a good deal greater.

It must be noted that thus far the tributaries have been supposed to be kept out of the main river. As this is impossible, the flow at Cairo of 1,500,000 cubic feet, in 1882, would result at Hays' Landing in a maximum flow about 200,000 cubic feet greater, to which is to be added the escape above Columbus, thus giving a still higher percentage of increase.

It is believed that these considerations sufficiently establish the principle that, with levees from Cairo down so high as never to be broken, whenever for ten days the flood discharge at Cairo exceeds a given amount, the maximum discharge at points below will be larger than that amount.

It must be noted that the steady flow at Cairo for ten days does not give the maximum flow at points below, for a confined river, but only a limit below which that flow can not fall. The actual flow for a confined river would be greater than this limit, from the fact that in the ten days at Cairo the maximum discharge would be greater than the least discharge (which has been used) in that time, and from the further fact that heavy rains in the valleys of the Mississippi and of its tributaries below Cairo might add over 200,000 cubic feet per second to the Cairo discharge.

C. B. COMSTOCK,
Colonel of Engineers, Bvt. Brig. Gen., U. S. A.,
President Miss. River Commission.

NEW YORK CITY, *June* 30, 1890.

APPENDIX D.

STATEMENT OF LENGTH AND DISTRIBUTION OF FRONT LEVEE LINES IN THE ALLUVIAL VALLEY OF THE MISSISSIPPI.

MISSISSIPPI RIVER COMMISSION,
OFFICE OF THE SECRETARY,
St. Louis, Mo., August 12, 1890.

SIR: Referring to my statement of the approximate length of levees existing before the late flood, forwarded last May 3, I now submit a revised statement, obtained from later data, and showing small changes from the approximate lengths:

Length of main front levees in miles.

Right bank.	Miles.	Left bank.	Miles.
Alton to Cape Girardeau	7¼	Alton to Cape Girardeau	47¾
Cape Girardeau to Cairo (Bird's Point)	7¾	Cape Girardeau to Cairo (Bird's Point)	1¾
Cairo to Helena	114¾	Cairo to Memphis	12
Helena to Cypress Creek (head Tensas Basin)	52¾	Memphis to Vicksburg	284
Cypress Creek to Louisiana State line	80¾		
Louisiana State line to Red River	223	Vicksburg to Baton Rouge	48¾
Red River to the Forts	274¼	Baton Rouge to the Forts	195¾
Total	752¼	Total	541¼

Total length of main front levees in alluvial valley, 1,294 miles.

The levee lengths from Alton to Grand Tower, and from Commercial Point to near Cairo, are derived from our surveys of 1888 and 1889; and from Grand Tower to Commercial Point, 47.3 miles, from the survey of 1884. It is not thought that any considerable addition has been made to these levees, especially since 1888.

The lengths from Cairo to Island No. 1 are from the survey of 1877; from Island No. 1 to Frame's Chute, near Memphis, excepting at Plum Point Reach, from the surveys of 1883 and 1885, and on right bank, from Frame's Chute to Commerce, from surveys of 1877 and 1878. These lengths are the same as those on the levee plots to Feb-

ruary, 1877, and it was stated at Captain Leach's office to Mr. Ockerson, whom I sent last January to compile levee information at the Memphis offices, that there were no records there of new levees on the St. Francis front, excepting at Plum Point Reach and Helena.

The lengths on the right bank from Walnut Bend to Cypress Creek, excepting near Helena, are from the surveys of 1881 and 1883, and are the same as shown on the levee plots of February, 1887.

The levee lengths of the Plum Point Reach, vicinity of Helena, Yazoo Front, Tensas Front down to Donaldsonville, and left bank, Baton Rouge to Donaldsonville, are revised to February 1, 1890. Statements of levee built since the date of our survey were derived from the district officers and from the levee engineers of the different levee districts.

Below Donaldsonville the lengths are taken from the 20,000-scale Coast Survey charts, showing topography of 1871 to 1875, and additions made thereon by the State engineer of Louisiana, bringing the data down to February 1, 1890. There is no information here of levees below the forts.

The lengths given do not include spurs nor loops not in the main front line; the Laconia Circle levee is shown as 18 miles long, but only its river front is considered as of the main front line. Neither do the lengths include railroad embankments.

Very respectfully, your obedient servant,

CHAS. F. POWELL,
Captain, Corps of Engineers.

The PRESIDENT MISSISSIPPI RIVER COMMISSION.

APPENDIX E.

REPORT OF CAPTAIN CHARLES F. POWELL, CORPS OF ENGINEERS, SECRETARY, MISSISSIPPI RIVER COMMISSION, AND ASSISTANT TO ITS CONSTRUCTION COMMITTEE; IN CHARGE OF THE ST. LOUIS OFFICE OF THE COMMISSION.

MISSISSIPPI RIVER COMMISSION,
OFFICE OF THE SECRETARY,
St. Louis, Mo., June 4, 1890.

At the beginning of the year, June 1, 1889, for which this report of operation is rendered, the available balance of the Commission appropriation was $8,886.26. No appropriation has been made during the year. Current expense, consisting principally of salaries, reduced the balance, so that the civilian members of the Commission have not been paid since November 15, 1889. These gentlemen preferred not to draw their salaries until more funds were provided, in order to permit an inspection of the river and its improvement works; it was authoritatively decided, however, that accruing obligations should be paid as far as the funds permitted; and since the statutes prohibit the incurrence of an expense in advance of an adequate appropriation therefor, except in certain special cases not here applicable, the result has been no river inspection since May, 1889, nor any Commission meeting since June of the same year. The balance of funds now available is $67.59, which will be exhausted during the month, leaving a deficiency at June 30, of $5,625 for Commissioners' salaries.

Of the Commission fleet, the survey-boats *Illinois* and *Kentucky* have continued to be temporarily loaned to the river survey, and the *Pioneer* to the general service. The house of the survey-boat *Mississippi* has also remained as at last report; its hull and that of the *Tennessee* have been condemned and disposed of; the house of the latter is now carried on an old general-service barge. The three steam-launches of the Commission are still temporarily transferred, one for use in the third district, and two in the fourth. The steamer *Patrol* was received back from the first and second districts in July, and then loaned to the river survey, where the steamer still remains.

No field operations were conducted during the year at the expense of the Commission appropriation. In the office special effort was made to obtain the notes of, and to compute the old and uncomputed discharge measurements, as well as current ones; the tabulation of results from the year's final computations are appended; this completes the discharge results to December 31, 1889, except those from measurements of 1889 at Red River Landing and Warrenton, and in Old River, and the Atchafalaya, whose final computation is now in hand, and also except the results at Carrollton, 1889, the notes of which have not been received. The appended tabulation also includes results of the 1890 discharge measurements at Wilson's Point, Skipwith Break, and New Madrid; notes of other discharge measurements of this year have not been received.

An old report, consisting of explanatory text, tabulated results and plates, upon the regimen elements of the river from Cairo to the Gulf at bank-full and medium stages, was published during the year in pamphlet form, and, with two additional tables, is here appended at the suggestion of the President of the Commission.

The report of the results of an investigation of the relation between mean bank height and mean high water at and near certain gauge stations below Cairo is also appended at General Comstock's instance.

An extended profile of levee and banks and showing certain water lines, required by a Commission resolution of 1885, was nearly completed and has been traced as far as made; I thought it desirable to bring this profile to a late date by showing upon it the later highest flood and the heights of present levees; the needed levee information has not yet all been obtained. An old plot of the levees of February, 18·7, on some sets of the inch-mile maps, made for distribution to the members of the Commission, was completed, and a plot of the levees of February, 1890, partly added thereto, and that part placed on a set of the 20,000-scale charts; all the required information as to the locations of the levees of 1890 is not yet received; the lacking part is soon expected. Copies of the completed profile and the maps showing levee lines can promptly be furnished the Commissioners after the last of the levee data is received.

An analysis of the costs of construction and maintenance of certain bank protection works, based upon the total expenditures therefor and the amount of effective work remaining, has been made, a summary of whose results, with explanations of the methods of deriving them, it is expected to lay before the Commission at an early time. Examination has also been made to find the costs of United States levees by accounting for all the expenditures from levee allotments; available data for determining the average costs per unit are rather meager, and a revision and extension of the examination are in view when more information is obtained as to the length and dimensions of certain levees.

A detailed and systematic investigation as to the relation of river-bed to river stage and as to the effect of outlets on the bed is well advanced. It is hoped to obtain results which will be deemed satisfactory because supported by observed facts. The encouragement as to outlets, and especially all-stage or nearly all-stage outlets, is not so good, since pertinent observations are very limited even after counting some old hydrographic plots of the Delta Survey and Coast Survey not heretofore used, it is believed, for these measurements. I judge it would be advantageous to have located cross-sections of the river below Red River systematically sounded at intervals throughout a year or more, making two to four sets of soundings at each section for a mean and having two to four sections at mile intervals at each locality and the localities taken where crevasses might be expected and then intermediate ones spaced all the way to the Head of the Passes.

Following the spirit of the Commission resolution that the publication of the gauge records be continued under the appropriation for the river survey, all work concerning water-gauges, river stages, etc., is reported upon in connection with the survey operations.

Mr. J. A. Ockerson, principal assistant in the office, returned to the service of the Commission last December. He has been mostly engaged, and it is expected to have him so continue, in the study of river physical data and the preparation of the levee record, as well as on some survey work. His familiarity with the field operations and care and accuracy of work make his assistance of much value. The discharge computations were generally made by Assistant Kivas Tully and Messrs. G. H. Johnson and L. M. Mann, to whom credit is due for care and patience in the work.

Respectfully submitted.

CHAS. F. POWELL,
Captain, Corps of Engineers.

The PRESIDENT OF THE COMMISSION.

APPROPRIATIONS.

For Mississippi River Commission, surveys, examinations, investigations, etc., Mississippi River and tributaries:

Act June 28, 1879	$175,000
Sundry civil act, June 16, 1880	150,000
Sundry civil act, March 3, 1881	150,000
Sundry civil act, August 7, 1882	150,000
Sundry civil act, March 3, 1883	150,000
	775,000

For Mississippi River Commission, assistant engineers, office expenses, and contingencies:	
Sundry civil act, July 7, 1884	$75,000
Sundry civil act, October 2, 1888	35,000
Deficiency act, October 19, 1888	25,000
	135,000
For surveys, examinations, and investigations, Mississippi River and tributaries:	
River and harbor act, July 5, 1884	75,000
For continuing survey, Mississippi River:	
River and harbor act, August 5, 1886	30,000
River and harbor act, August 11, 1888	75,000
	105,000

Mississippi River improvements under the Mississippi River Commission.

For river improvements above Cairo, including certain specified harbors and localities:*	
Act, July 5, 1884	$720,000
For river improvement below Cairo:	
Act, March 3, 1881	1,000,000
Act, January 19, 1884	1,000,000
Act, August 5, 1886	1,531,250
Act, August 11, 1888	1,850,000
	5,381,250
For river improvements below Cairo, including certain specified harbors and localities:	
Act, August 2, 1882	4,123,000
Act, July 5, 1884	1,150,000
	5,273,000
For specified localities below Cairo:	
Memphis (act, July 5, 1884)	200,000
Memphis (act, August 5, 1886)	56,250
New Orleans (act, August 5, 1886)	75,000
New Orleans (act, August 11, 1888)	200,000
Red and Atchafalaya rivers (act, August 5, 1886)	187,500
Red and Atchafalaya rivers (act, August 11, 1888)	250,000
Greenville (act, August 5, 1886)	37,500
Greenville (act, August 11, 1888)	75,000
Vicksburg (act, August 5, 1886)	75,000
Vicksburg (act, August 11, 1888)	150,000
Hickman (act, August 5, 1886)	18,750
Hickman (act, August 11, 1888)	70,000
Columbus (act, August 5, 1886)	18,750
Columbus (act, August 11, 18-8)	25,000
Lake Bolivar (act, August 11, 1888)	150,000
Helena (act, August 11, 1888)	75,000
	1,663,750

* Eight hundred thousand dollars were appropriated by the act of August 2, 1882, for expenditure in accordance with the plans, specifications, estimates, and recommendations of the Mississippi River Commission, but the work was not assigned to the supervision of the Commission.

Money statement.

July 1, 1889, amount available		$6,229.85
April 15, 1890, amount received by transfer of property to other appropriation	$278.16	
May 27, 1890, amount received by transfer of property to other appropriation	116.64	
		394.80
		6,624.65
June 30, 1890, amount expended during fiscal year, exclusive of outstanding liabilities, July 1, 1889	6,508.15	
Outstanding liabilities *	116.50	
		6,624.65

List of civilian engineers employed during the year to May 31, 1890, by the Mississippi River Commission under sundry civil act of October 2, 1888.

Name and place of residence.	Time employed. m.	Time employed. d.	Compensation per month.	Where employed.	Work on which employed.
J. A. Ockerson, St. Louis, Mo	1	15	$200.00	St. Louis	Mississippi River Commission.
Kivas Tully, St. Louis, Mo	2	0	175.00	do	
E. H. Twining, New York, N. Y	3	0	175.00	New York	

CHAS. F. POWELL,
Captain Corps of Engineers,
Secretary Mississippi River Commission.

Approximate value of plant belonging to appropriations for Mississippi River Commission and survey of Mississippi River.

Mississippi River Commission. Item.	Amount.	Survey of Mississippi River. Item.	Amount.
One steam-boat, patrol	$10,000	Three launches, Nos. 5, 6 and 7	$5,400
Three launches, Nos. 1, 3, and 4	3,000	Current meters, and outfit	300
Two quarter-boats	2,000	Outfit	500
Three quarter-boat cabins	900	Tools and appliances	25
Skiffs, etc	25	Office instruments	113
Outfit	2,825	Type, etc	60
Tools and appliances	575		
Surveying instruments	12,000	Total	6,398
Drawing instruments	700		
Office furniture	700		
Printing presses, etc	675		
Current meters, and outfit	1,000		
Total	34,400		

* Does not include salaries, $5,625, of civilian members from November 16, 1889, to June 30, 1890.

Chart statement.

	Mississippi River Commission alluvial valley map.	Survey of Mississippi River.	
		Inch-mile chart, Cairo to head of passes.	Detail charts, $\frac{1}{2400}$ scale, Cape Girardeau to Donaldsonville.*
	Sets.	*Sets.*	*Sheets.*
On hand May 31, 1889	555	404	17,217
Received			36,000
Sold	28	$101\frac{1}{4}$	37
Issued free	45	$74\frac{3}{4}$	9,980
On hand June 1, 1890	482	319	43,200

* Seventy-one charts to the set; 54 charts now published.

COMMERCIAL STATISTICS.

Statement of freight carried between St. Louis, Missouri, and New Orleans, Louisiana, by the New Orleans Barge Line, 1868 to December 31, 1889, inclusive, furnished by Mr. H. C. Haarstick, president of the St. Louis and Mississippi Valley Transportation Company.

Year.	Transported down stream.			Transported up stream.	Total carried.
	Package freight.	Bulk grain.	Total down stream.		
	Tons.	*Bushels.*	*Tons.*	*Tons.*	*Tons.*
1868	85,580	.....	85,580	16,500	102,080
1869	92,620	.....	92,620	22,300	114,920
1870	173,986	.....	173,986	58,080	232,066
1871	136,774	336,960	146,134	61,550	207,684
1872	202,430	1,847,880	253,760	77,792	331,552
1873	116,119	1,482,840	157,309	33,226	190,535
1874	117,266	1,536,840	159,956	19,975	179,931
1875	78,264	332,640	87,504	18,053	105,557
1876	92,255	1,915,920	145,475	22,619	168,094
1877	85,153	4,429,080	208,183	11,769	219,952
1878	114,075	5,887,080	277,605	19,258	296,863
1879	110,935	6,657,120	295,855	19,582	315,437
1880	115,400	17,022,960	588,260	24,283	612,543
1881	125,000	12,933,000	513,527	101,018	614,545
1882	80,090	8,189,425	328,411	64,949	393,360
1883	95,424	11,178,303	412,884	41,055	453,939
1884	117,528	7,093,424	313,029	25,572	338,601
1885	97,745	8,811,487	339,677	18,151	357,828
1886	81,717	9,215,361	334,596	47,651	382,247
1887	87,930	11,563,979	417,191	78,453	495,644
1888	82,277	8,119,881	310,137	47,118	357,255
1889	96,508	14,999,685	515,211	34,253	549,464
Total	2,385,076	133,553,865	6,156,890	863,207	7,020,097

In addition to the above this company report having transported southward between the years 1868 and 1877 an average quantity of 15,000 tons of ice per annum, and between the years 1878 and 1889 an average quantity of 12,000 tons of ice per annum.

Mr. Haarstick says "in this connection would like to refer to the great difference in tonnage in the column of bulk grain in the past ten years. The cause for this is short crops in this country whenever the amount transported falls below 9,000,000 bushels. The amount we now transport could in my opinion be doubled with almost the same plant that this company now owns, if we had an improved river with 10 feet of water in the channel the year round. Usually when the new crop of wheat is sent into the market we are troubled by low water, and by reason of it can only load

about 40 per cent. of the capacity in each barge, and in addition to this our boats consume at least two or three times the time in going from St. Louis to New Orleans; this necessitates the advance of rates of freight, and in consequence lower markets for the cereals in our market."

Customs statistics for the port of New Orleans for 1889.

Shipping.	Entrances.	Clearances.	Registered tonnage.
	No.	*Tons.*	*Tons.*
Coastwise	360	248	772,062
Foreign	366	845	1,833,218

Value of foreign imports (includes $415,260 received in cars)	$14,740,474
Value of foreign exports	100,609,458

Number and tonnage of merchant vessels navigating the Mississippi River below Cario, Illinois, January 1 to December 31, 1889, sea-going vessels not included.

[Compiled at office of the Mississippi River Commission, from reports furnished by the United States local inspectors of steam-vessels in the fourth, sixth, tenth, and part of seventh inspection districts, and statement of vessel-owners.]

Hailing port.	Main terminus of route.	Steam-boats, passenger and freight.	Steam-boats, towing.	Steam-boats, transfer.	Steam-boats, ferry.	Steam-boats, miscellaneous.	Barges and produce boats.	Maximum loaded draught.	Registered tonnage.	Carrying capacity.	Freight carried (approximate).	Persons employed (approximate).
		No.	*No.*	*No.*	*No.*	*No.*	*No.*	*Feet.*	*Tons.*	*Tons.*	*Tons.*	*No.*
Pittsburgh	New Orleans	.....	2	.....	.....	.....	.....	.....	1,116.01	1,495.45	.....	50
Pittsburgh*	Memphis and New Orleans	.....	15	.....	.....	.....	1,000	8	*	450,000.00	1,000,000	525
Wheeling	Various	.....	6	.....	.....	.....	82	8½	1,026.75	1,026.75	45,050	208
Cincinnati	New Orleans and Memphis	13	.....	.....	.....	.....	.....	9½	13,416.75	16,818.00	230,926	1,115
Cincinnati	New Orleans and Louisiana Bend	.....	6	.....	.....	.....	51	.....	*	26,000.00	157,000	
Louisville	New Orleans	8	.....	.....	.....	.....	.....	.....	2,499.25	3,099.07	.....	200
Cairo	Columbus, Ky	.....	.....	1	.....	.....	.....	3½	312.04	312.04	.....	10
St. Louis	New Orleans	16	12	.....	.....	.....	.....	8	22,196.80	29,743.71	400,000	1,800
St. Louis	New Orleans	.....	.....	.....	.....	.....	80	9 8/12	*	128,640.00	700,000	
Memphis	Various	34	11	4	11	7	.....	.....	11,286.73	18,072.67	846,700	2,010
New Orleans	Various	107	13	5	13	.....	28	.....	*	†67,500.00	†545,000	4,440
Total		178	65	10	24	7	1,241	.....	51,854.33	742,707.69	‡3,924,676	10,358

* Not known.

† Estimated.

‡ The transportation of this quantity of freight by rail within the same period would require the departure from a given point of a train of 20 cars, 15 tons each, about every 40 minutes.

Total number of steam-boats, all classes, barges, and produce boats, 1,525.

The president of the St. Louis and New Orleans Anchor Line states that the extreme low water of the fall and part of the summer, 1889, prevented its packets from loading to more than about one-half their capacity north of Cairo, and that for quite a time the packets could not load to near their carrying capacity north of Memphis; as the company's down traffic originates at the north of Cairo the amount was consequently diminished by an unusual low water.

REGIMEN ELEMENTS OF THE MISSISSIPPI RIVER, BANK FULL AND MEDIUM STAGES, CAIRO TO THE GULF OF MEXICO.

[From surveys by the Mississippi River Commission, the Corps of Engineers, U. S. A., and the U. S. Coast and Geodetic Survey, 1871–1884. Compiled under the direction of Prof. Henry Mitchell, member Mississippi River Commission, and of the secretary of the Commission, by L. C. Jones, assistant engineer, 1887, with additional tables compiled at the secretary's office, 1890.]

REPORT OF ASSISTANT ENGINEER L. C. JONES ON THE HISTORY OF THE WORK, ETC.

Work upon the high-water regimen of the Mississippi River was begun in April, 1881, and the first portion (since revised), from Cairo to Memphis, which was blueprinted the following September, was based upon a compilation of cross-section elements by Mr. Robert E. McMath, as far as Ashport, Tenn., and the remaining data to Memphis compiled by myself from the surveys of Col. J. A. Monroe, and the surveys of Plum Point Reach by Mr. W. H. Powless. (See supplemental report.) The work was then discontinued till the end of the field season of 1881–'82, and not resumed till about May, 1882. It was interrupted each fall and not resumed till the following spring, and was also subject to the interruptions consequent to the determination of elements of cross-sections, bank-full and medium stage, for each two miles of river.

The work was completed and plotted to Donaldsonville, La., on July 28, 1885, where the surveys of the Mississippi River Commission met those of the U. S. Coast and Geodetic Survey. On August 31, 1885, I left St. Louis for Washington, D. C., according to instructions from Capt. Thomas Tuttle, secretary Mississippi River Commission, arriving there September 2, and began that day tracing the hydrographic sheets in the Coast Survey Office, interpolating soundings from the original note-books where there was not a sufficient number of them plotted to give a good cross-section. These charts, from Donaldsonville to within a couple of miles of the Head of the Passes, were on a scale of 1 : 20,000, and were ten in number. The short reach above the passes comprised two charts, one on a scale of 1 : 4,800, and the other 1 : 10,000. There were five charts covering the passes, viz: Southwest Pass, two, scale 1 : 4,800; South Pass, two, scale 1 : 4,800; Pass à l'Outre, one, scale 1 : 20,000. This latter pass is considered as the main river on the plot, and the elements of cross-section, etc., considered only as far as the head of East Pass.

These tracings completed, I returned to St. Louis, arriving on Friday evening, September 25, 1885, and the next day commenced the measurements necessary. The cross-sections had first to be increased to a width equal to a scale of 1 : 10,000, and then the profiles plotted, etc., the work being completed January 26, 1886.

DESCRIPTION OF PLOT.

The High Water Regimen of the Mississippi River is intended to show the relations which the elements of cross-sections bear to each other.

To illustrate these the river has been divided into sections of various lengths, attention being paid to islands and their accompanying chutes, it being always the plan to make a section begin at the head and end at the foot of a chute, where one of any appreciable magnitude exists. In all other instances it has been the rule to divide the river into bends and half-bends, at the point of crossing, or reversion of curvature. The plot shows the mean area, mean width, mean depth, mean thalweg depth, by which is meant a channel having a width of five hundred feet, mean maximum depth; curvature in ratio of arc and chord, and in degrees per mile; slope per mile; and oscillation for each section of the river. The mean of each element of each section is plotted on the same ordinate, which is that drawn through a point equal to the distance, in feet, of the middle of the section below Cairo. All values relate to a bank-full stage. Each value plotted is the arithmetical mean of all observations of each element of cross-section in the section of the same number in the sketch of the river.

The following table gives the distances between cross-sections, etc.:

Locality.	Distance.	Surveyed by.	Date.
Between Cairo and Ashport	One-half mile	Col. J. A. Monroe	1879
Between Ashport and Fulton	One-fifth mile	Mr. W. H. Powless	1880
Between Fulton and Memphis	One-half mile	Col. J. A. Monroe	1879–'80
Between Memphis and Commerce	One-fourth mile	Gen. C. B. Comstock	1877–'79
Between Commerce and Austin	....do	Mr. J. A. Ockerson	1880
Between Austin and Delta	....do	....do	1878
Between Delta and Arkansas City	....do	.. do	1881–82
Between Arkansas City and Greenville	One-fifth mile	....do	1881
Between Greenville and Lake Providence	One-third mile	Mr. G. Y. Wisner	1881–'82
Between Lake Providence and Paw-Paw Island.	One-fourth mile	Mr. C. M. Winchell	1882
Between Paw Paw Island and Big Bayou	....do	Mr. J. A. Ockerson	1881
Between Big Bayou and Natchez	... do	Mr. L. L. Wheeler	1882–'83
Between Natchez and Bayou Sara	....do	Mr. J. A. Ockerson	1882–'83
Between Bayou Sara and Donaldsville	....do	Mr. C. M. Winchell	1883
Between Donaldsville and Gulf of Mexico.	....do	U. S. Coast and Geodetic Survey.	1871–'79

Horizontal distances were measured on a line midway between banks and plotted to a scale of 50,000 feet = 1 inch. Full lines in elements of cross-sections show values for main channel alone. Broken lines, and broken and dotted lines, in area, width, and mean depth, show respectively the main channel and principal side channel combined, and all channels combined.

Mean maximum depth is represented by a dotted line. The curvature in ratio is expressed by a full line terminating in the symbol $\wedge$, and the curvature in degrees per mile, which has the same origin as the former, is expressed, when exceeding the ratio, by a broken line beyond the ratio symbol, and ending in the symbol $\times$, and when less than the ratio, simply by the symbol $\times$ crossing the full line.

Slope per mile is expressed by simple full lines, and where it conflicts with the oscillation the origin of the slope ordinate is denoted by a short line drawn at right angles to it.

Oscillation is denoted by full lines, which are cut at the upper end by a sloping line drawn between the gauge points, that are used to determine the oscillation.

When the oscillation ordinates extend beyond the slope ordinates, the origin of the slope ordinate is marked by a short line at right angles to itself, and terminated by a small circle, and the oscillation ordinate continued in a broken line to its contact with the sloping line drawn between the gauges.

The sketch of the river on the plot is not drawn to scale but traced from the Levee Map, by Messrs. Molitor & Craig, and has been broken and shortened in several places, in order to make the numbered sections correspond as nearly as practicable with the ordinates of mean elements.

The sketch was broken at sections Nos. 138 and 167, and swung to the right. The index sheets drawn in the sketch refer to the inch-to-the-mile charts by Mr. Molitor. At section No. 135, the line representing the mean width was broken and raised, in order to prevent confusion with the thalweg line, which it would have crossed at several points if left undisturbed.

The base of the areas is taken at 180,000 square feet, and plotted to a scale of 60,000 square feet = 1 inch.

The base of widths is taken at 4,000 feet, and plotted to a scale of 1,200 feet = 1 inch.

Mean depth, mean thalweg depth, and mean maximum depth, are all plotted from the same base = 0, and are plotted to a scale of 30 feet = 1 inch.

Curvature in ratio and degrees per mile are referred to the same base = 0. In the scale of the former, .3 = 1 inch, and in the scale of the latter, 6° = 1 inch.

Slope per mile is plotted to a scale of .3 feet = 1 inch, and begins at (0) zero.

Oscillation is referred to that at Memphis = 36.1 feet, and is plotted to a scale of 6 feet = 1 inch. At Baton Rouge and Carrollton the plane of reference is lowered to 11 feet and 0 feet, respectively.

METHODS OF OBTAINING RESULTS.

The cross-sections used were those plotted on the office charts, scale 1:10,000, of which tracings on linen were made, and the soundings thereon reduced to a bank-full stage. All cross-sections were plotted to a horizontal scale of 1:10,000, and a vertical scale of 30 feet = 1 inch. Each cross-section was then carefully measured and checked with a planimeter, which gave the area.

The width, thalweg depth, and maximum depth of each cross-section were scaled off, and the mean depth obtained by dividing the area by the width.

The results of the measurements of these elements were tabulated in regular order, showing the value of each element in each cross-section. To obtain the values plotted, all the cross-sections within the limits of each section of river were grouped together, their individual elements summed, and a mean taken, which gave mean area, mean width, etc., for each section of river. This applies only to elements of cross-section, *i. e.*, area, width, mean depth, thalweg depth and maximum depth.

Mean slope was determined from the table of slopes, high water 1882, Mississippi River Commission records. (Report Mississippi River Commission, 1885, pages 2907–2912, inclusive.) The slopes per mile between points within the limits of a section of river were taken, and total slope for the section computed. This result being divided by the total number of miles in the section, gave the slope per mile for that section.

Curvature in ratio was obtained by measuring the distance in thousand feet chords along the mid-bank line between the extremities of each section, and dividing the distance thus obtained by the length of chord or straight line joining these extremities.

Curvature in degrees per mile was obtained by drawing circular curves, compounding or reversing them as necessary, carrying the line of curvature as nearly as possible along the mid-axis of the stream, without producing confusion by too many combinations of curves. The number of degrees of departure in a section were summed, and the result divided by the number of miles in the section, measured in thousand feet chords, along the line of curvature. The quotient thus obtained was the curvature in degrees per mile for that section.

The curves and distances were plotted and measured on a set of the small office charts, scale 1:63,360.

Oscillation was determined by taking the differences between the highest and lowest known readings on the reliable gauges. They are to be found in the Chief Engineer's Report, 1881, Part II, p. 1439, the high water readings of 1882–'83–'84, which at some of the guages are the highest known, from the Mississippi River Commission records. (Mississippi River Commission Report, 1885, pages 2909–2915, inclusive.) In plotting the elements of the passes, Pass á Loutre was considered the main branch, and the other two were treated in regard to area, width, and mean depth, as though they were chutes. The maximum depth, thalweg, and curvature, both in ratio and degrees per mile, of all three passes, are plotted separately, Pass á Loutre, however, being considered only as far as the head of East Pass, and the ordinate for the mean distance for the section plotted as the distance measured to that point. The right line represents Pass á Loutre, and Southwest Pass and South Pass are respectively represented by a broken line, and a broken and dotted line. Slope was carried only to Carrollton, there being no levels below that point.

Respectfully,

L. C. JONES,
Assistant.

SUPPLEMENTAL REPORT OF ASSISTANT ENGINEER L. C. JONES.

On August 9, 1886, I received orders from Capt. Thomas Turtle, secretary Mississippi River Commission, to revise the work of the High Water Regimen of the Mississippi River between Cairo and Memphis, and Commerce Cut-off, St. Louis Landing, Ark.

The methods employed in the determination of values are the same as used in the original work, but the data used were the surveys of Assistants J. A. Ockerson, L. L. Wheeler, and C. M. Winchell, which were made in 1883–'84–'85. In these surveys the cross-sections were taken at an average of every one-fourth mile, and frequently as many as five were taken in that distance.

The work has been replotted, and the origin of distance is the United States gauge at Cairo, and the mean of each element in each section is plotted on the same ordinate, which is that drawn through a point equal to the distance in miles of the middle of the section below the gauge at Cairo.

L. C. JONES,
Assistant.

MAY 31, 1887.

Gauge-readings relating to the means in the following tables.

Gauges.	Distance between gauges.	Elevation of gauge zeros above Cairo datum.	Slope per mile between gauges.	Gauge readings.				Extreme oscillation, 1872–1890.
				High water of 1882.	Low water of 1882.	Medium stage.*	Bank-full stage.	
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Cairo	0.0	290.84	.....	51.87	7.30	29.58	39.29	53.17
Columbus	21.3	229.14	0.27	102.77	67.26	85.02	94.00	.....
New Madrid	47.8	276.04	0.33	41.33	3.70	22.51	33.09	.....
Cottonwood Point	53.7	250.62	0.51	37.50	3.60	20.55	36.00	.....
Memphis	107.2	203.97	0.45	35.15	3.50	19.33	31.1	36.25
Mhoon's Landing	45.9	181.48	0.44	39.80	5.90	22.85	34.7	.....
Helena	30.6	161.98	0.47	47.20	8.60	27.90	43.6	48.30
White River	86.7	128.73	0.37	48.40	9.70	29.05	44.4	48.40
Arkansas City	45.1	116.47	0.32	47.07	7.50	27.28	41.8	.....
Lake Providence	104.0	89.62	0.31	38.32	5.90	22.11	36.5	42.25
Vicksburg	57.0	66.04	0.31	48.75	7.60	28.17	44.1	52.91
St. Joseph	51.0	52.74	0.30	44.90	7.80	26.35	40.4	.....
Natchez	51.8	36.89	0.26	47.75	9.70	28.72	36.3	47.75
Red River Landing	65.0	23.85	0.20	48.50	9.10	28.80	36.3	48.50
Port Hickey	44.7	13.68	0.14	47.90	17.00	32.45	44.4	.....
Baton Rouge	23.3	20.06	0.21	35.95	6.18	21.06	33.0	35.05
Plaquemine	20.2	21.06	0.13	31.30	3.80	17.55	28.0	.....
College Point	49.5	21.24	0.092	23.13	2.48	12.80	20.4	.....
Carrollton	54.0	20.91	0.096	14.95	1.00	7.95	8.9	17.30
Gulf Level	102.5	.....	0.097	.....	.....	.....	.....	.....

*Mean of high and low water of 1882.

Revised table of regimen of the Mississippi River, at bank-full stage, from Cairo to the Gulf of Mexico.

Number of section.	Distance from Cairo.	Length of section.	Mean area.	Mean width.	Mean depth.	Mean thalweg depth.	Mean maximum depth.	Slope per mile, high water, 1882.	Ratio of curvature.	Curvature in degrees.			
										Total.		Per mile.	Distance on arc.
	Miles.	*Feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*		° ′		° ′	*Feet.*
1	7.7	47,000	197,191	4,412	44.9	69.8	73.5	0.476	1:1.06	124	15	13 46	47,760
2	15.3	33,500	194,000	5,236	39.5	70.2	77.5	0.558	1:1.47	158	25	24 07	34,700
Chute, Islands 1 and 2			9,760	488	35.6								
Do			10,500	840	32.7								
3	20.4	20,200	191,775	3,273	61.6	84.5	92.0	0.550	1:1.22	146	50	37 39	20,600
4	25.4	33,450	191,962	5,079	39.4	57.5	64.9	0.449	1:1.05	185	15	28 46	34,000
Chute, Island 5			46,944	1,786	34.8								
5	30.9	24,500	216,833	5,460	40.1	64.5	71.9	0.347	1:1.11	105	10	22 08	25,200
6	35.7	25,700	196,345	4,466	45.2	63.2	93.7	0.289	1:1.15	107	45	21 05	27,000
Chute, Island 6			7,125	450									
7	40.4	24,400	218,875	4,860	45.4	63.4	68.1	0.279	1:1.05	72	20	14 51	25,700
8	46.4	39,000	173,962	4,014	44.1	69.9	77.2	0.393	1:1.43	165	55	21 34	40,600
Chute, Island 8			56,781	2,134	37.5								
9	53.6	36,800	209,672	4,873	43.4	63.5	68.9	0.188	1:1.02	87	30	12 31	36,900
10	60.3	33,300	236,048	7,544	31.8	58.8	64.2	0.228	1:1.24	153	10	28 48	33,600
11	65.3	20,400	196,475	5,716	34.7	64.7	72.7	0.228	1:1.01	46	20	11 42	20,900
12	70.2	30,600	211,565	5,874	36.4	61.1	67.1	0.574	1:1.60	211	35	34 55	32,000
13	76.6	36,800	260,010	6,971	37.4	54.2	58.5	0.450	1:1.03	223	10	30 12	39,000
14	84.4	46,300	216,401	5,310	40.9	67.0	73.5	0.593	1:1.45	199	35	21 46	48,400
15	92.2	36,020	214,080	6,372	34.8	69.7	76.9	0.532	1:1.65	194	55	27 18	37,700
16	99.2	38,380	208,630	5,040	41.9	63.5	70.3	0.520	1:1.57	177	00	22 48	41,000
17	106.4	36,600	186,964	4,928	39.3	71.7	78.5	0.629	1:1.90	195	30	26 49	38,500
18	111.4	16,900	203,708	4,887	41.9	55.3	58.6	0.494	1:1.00	38	00	12 08	16,500
19	116.2	34,000	204,822	4,880	42.6	57.3	66.1	0.464	1:1.13	152	20	22 55	35,100
Chute, Islands 16 and 17			10,833	666									
Chute, Island 18			80,203	2,647	37.9								
Second Chute, Island 18			14,904	828	35.6								
20	121.3	19,300	158,258	3,644	42.9	59.4	66.0	0.426	1:1.03	39	00	10 39	19,300
Chute, Islands 20 and 21			33,759	1,504	36.2								
21	127.6	47,500	194,630	4,813	41.2	58.5	62.8	0.213	1:1.23	132	00	14 10	49,200
22	135.7	37,800	188,529	4,746	40.9	68.1	72.8	0.566	1:2.33	211	15	28 40	38,900
23	141.3	21,500	167,989	4,501	37.8	69.7	78.1	0.534	1:1.33	136	10	30 04	23,900
Chute, Island 25			3,911	406									
Chute, Islands 26 and 27			28,038	937	33.3								
24	145.1	18,100	170,640	3,935	43.5	63.4	69.1	0.527	1:1.10	104	00	29 33	18,600
25	149.8	32,400	159,868	4,711	34.3	61.0	67.3	0.535	1:1.22	193	30	29 52	34,200
26	155.5	27,280	188,604	5,034	39.1	56.3	60.7	0.529	1:1.09	146	00	27 14	28,300
Chute, Ashport Bar			19,062	1,270	33.0								
27	160.8	28,900	236,521	7,447	32.2	52.6	56.6	0.878	1:1.15	130	30	24 05	28,600
28	165.6	21,850	200,300	5,427	38.4	51.2	54.6	0.539	1:1.15	93	15	22 22	22,000

Revised table of regimen of the Mississippi River, at bank-full stage, from Cairo to the Gulf of Mexico—Continued.

Number of section.	Distance from Cairo.	Length of section.	Mean area.	Mean width.	Mean depth.	Mean thalweg depth.	Mean maximum depth.	Slope per mile, high water, 1882.	Ratio of curvature.	Curvature in degrees.				Distance on arc.
										Total.		Per mile.		
	Miles.	*Feet.*	*Sq. Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*		°	′	°	′	*Feet.*
Chute, Osceola Bar			37,325	1,331	35.2									
29	172.0	45,000	207,191	4,800	48.2	62.8	76.5	0.343	1:2.12	224	00	25	27	46,500
30	178.5	24,250	220,236	5,178	42.6	53.1	57.6	0.454	1:1.02	49	00	10	36	24,400
Chute, Island 34			34,125	1,434	38.5									
31	183.4	27,200	189,533	3,590	57.1	81.3	94.7	0.804	1:1.62	170	30	31	41	28,400
32	191.0	53,330	160,911	4,362	37.5	59.5	68.0	0.472	1:1.98	177	30	16	37	56,400
Chute, Island 35			87,493	3,244	32.7									
33	199.8	39,900	193,493	4,584	42.6	67.1	74.9	0.326	1:1.50	180	30	23	17	40,900
34	207.5	40,800	154,430	3,463	48.5	71.5	80.3	0.522	1:1.24	216	00	27	25	41,600
Chute, Brandywine Island			68,450	3,719	31.0									
35	216.2	50,900	187,348	6,003	32.5	58.7	65.8	0.433	1:1.67	279	00	27	19	54,000
Chute, Beef Island			42,482	1,343	31.3									
36	222.9	20,700	196,365	5,154	38.5	64.8	72.6	0.447	1:1.16	112	00	27	31	21,500
37	227.0	21,920	174,687	4,502	38.8	68.1	79.2	0.447	1:1.42	218	00	48	27	23,800
Chute, Old Hen Island			12,375	1,370	31.9									
38	231.0	20,800	132,094	2,995	44.1	86.0	89.0	0.322	1:1.17	121	45	31	23	20,500
39	236.4	36,300	129,375	4,868	26.6	46.1	49.1	0.451	1:1.32	179	45	25	38	37,009
Chute, President's Island			78,453	2,205	29.4									
40	242.9	31,600	191,433	5,269	36.3	52.0	53.4	0.284	1:1.13	82	00	13	58	31,000
41	249.8	41,800	158,490	4,458	35.6	57.1	60.3	0.620	1:1.63	199	00	24	32	42,800
42	256.6	30,040	169,344	4,894	34.6	49.6	50.9	0.477	1:1.14	101	00	17	33	30,400
43	263.0	37,060	134,266	4,728	28.4	41.7	43.8	0.358	1:1.05	88	45	11	00	37,800
44	269.7	34,300	185,107	6,867	27.0	56.2	59.0	0.239	1:1.18	205	00	30	20	35,700
45	276.0	32,100	194,551	6,637	31.4	65.3	79.6	0.347	1:1.76	267	50	40	53	34,600
46	281.0	20,000	175,925	4,476	39.1	57.2	70.3	0.388	1:1.18	229	30	58	33	20,700
Walnut Bend			68,703	2,350	35.8									
47	287.0	44,700	189,819	5,075	38.5	65.1	74.5	0.404	1:1.71	343	15	34	42	52,200
48	295.6	45,200	227,892	5,885	40.5	67.6	73.4	0.369	1:1.82	222	20	24	04	48,800
49	302.2	25,000	251,304	6,923	39.4	74.3	81.4	0.383	1:1.14	144	25	28	02	27,200
50	307.3	28,200	215,371	5,042	43.2	69.7	77.2	0.570	1:1.01	46	50	8	50	28,000
51	312.2	24,100	227,168	5,735	41.2	74.7	90.1	0.566	1:1.22	110	40	24	26	23,900
52	317.3	29,920	202,804	4,428	46.2	73.3	80.6	0.436	1:1.01	82	00	14	32	29,800
53	324.3	43,280	165,974	3,604	46.4	77.8	89.7	0.463	1:1.73	212	05	25	13	44,400
54	330.8	25,900	179,708	5,039	37.6	67.0	77.1	0.447	1:1.52	178	10	36	53	25,500
Chute, Island 62			11,293	407	34.2									
Chute, Island 63			51,856	1,665	34.5									
55	334.5	13,200	198,011	4,814	42.0	65.4	72.9	0.447	1:1.10	43	50	16	32	14,000
56	338.0	23,400	171,342	3,692	47.5	76.0	82.5	0.447	1:1.11	96	30	23	57	21,300
57	344.3	43,100	180,598	4,929	37.1	75.2	85.5	0.419	1:2.61	239	35	31	09	40,600
58	352.3	41,000	148,296	3,770	39.3	69.9	75.1	0.282	1:2.55	224	26	28	19	41,800

Chute, Island 66			25,229	1,170	35.1								
59	357.9	18,100	181,911	3,916	46.4	64.2	68.7	0.358	1:1.00	44	50	12	58	18,400
60	361.8	24,000	155,986	4,129	37.8	66.6	70.7	0.233	1:1.78	190	20	41	50	24,000
Chute, Island 68			60,425	1,992	35.4								
61	365.8	17,500	170,109	3,420	49.7	70.2	72.6	0.262	1:1.01	54	50	16	28	17,600
62	370.2	28,900	164,489	3,755	43.8	76.5	82.3	0.358	1:1.35	179	10	32	03	29,500
Chute, Island 69			20,667	707	41.5								
63	374.2	13,500	162,771	3,375	48.2	95.8	103.8	0.143	1:1.05	61	30	23	45	13,700
64	379.1	38,700	183,942	4,301	42.8	77.1	83.5	0.242	1:1.93	198	50	26	31	39,600
65	385.4	27,300	171,625	4,068	42.2	74.1	78.6	0.311	1:2.01	216	20	40	58	27,900
Scrub Grass Chute			21,125	997	38.1								
66	390.3	24,900	183,488	4,022	45.6	73.7	79.6	0.311	1:1.09	92	00	19	53	25,700
67	394.5	18,800	171,979	3,519	48.9	89.6	94.8	0.455	1:1.64	75	00	20	19	19,500
68	398.3	21,300	198,019	4,204	47.1	74.2	78.4	0.360	1:1.13	106	00	25	32	21,900
69	402.9	28,200	180,125	3,862	46.6	80.1	86.2	0.160	1:1.08	127	10	23	38	28,400
70	407.8	22,800	196,375	3,967	49.5	100.1	110.1	0.307	1:1.85	197	30	45	18	23,000
71	411.7	18,700	183,694	3,887	47.3	71.5	75.8	0.307	1:1.00	66	10	18	02	19,400
72	415.0	15,700	163,250	4,780	34.2	73.9	80.2	0.350	1:1.24	180	30	39	25	17,500
Chute, Island 75			53,575	1,530	34.4								
73	418.2	18,800	183,437	4,053	45.2	72.9	77.1	0.297	1:1.11	46	40	13	56	17,700
74	421.3	14,000	193,708	5,173	37.5	78.7	81.6	0.297	1:1.01	66	30	24	32	14,300
Chute, Catfish Towhead			27,690	1,130	35.1								
75	427.0	46,300	191,875	4,129	46.5	90.4	98.6	0.244	1:2.05	210	20	25	01	44,400
76	434.3	30,800	224,600	5,375	45.8	73.2	76.3	0.405	1:1.77	167	10	28	06	31,400
77	439.9	28,200	197,863	3,440	58.1	95.2	99.9	0.575	1:1.25	126	30	23	31	28,400
78	444.8	23,600	205,096	5,623	36.5	72.0	77.0	0.141	1:1.16	131	15	27	24	25,300
79	450.8	39,300	185,298	3,612	51.3	88.5	92.1	0.442	1:3.67	244	30	32	26	39,800
80	459.0	47,000	184,799	4,118	44.9	81.3	85.5	0.189	1:2.40	226	00	24	52	48,000
Chute, Island 82			9,190	920	38.5								
81	467.6	44,400	187,703	3,859	48.6	86.0	89.7	0.330	1:2.04	220	30	37	28	42,400
82	476.3	47,200	188,535	4,312	43.7	73.4	75.5	0.361	1:3.52	232	15	25	15	48,600
83	482.7	20,800	221,786	5,181	42.8	62.8	64.9	0.317	1:1.00	25	40	6	31	20,800
84	487.5	29,000	217,042	5,354	40.5	65.6	69.3	0.347	1:1.27	121	00	22	33	28,300
85	492.3	22,200	198,844	4,616	43.1	73.5	76.2	0.243	1:1.07	92	00	21	36	22,590
86	495.8	14,600	190,781	3,915	48.7	95.1	97.7	0.222	1:1.01	81	30	28	42	15,000
87	499.0	19,800	176,750	4,223	41.9	78.4	82.9	0.348	1:1.17	93	20	25	01	19,700
88	503.1	23,400	187,438	4,240	44.2	65.4	68.2	0.481	1:1.08	36	00	8	22	22,709
Chute, formerly Bullitt's Towhead			14,040	570	41.9								
89	507.6	23,600	180,417	5,465	33.0	77.1	84.0	0.475	1:1.63	153	00	36	41	22,000
90	511.4	16,500	190,313	4,303	44.2	71.6	77.9	0.385	1:1.01	50	00	16	05	16,400
91	514.7	18,900	181,300	4,612	39.3	66.2	68.7	0.385	1:1.04	65	05	19	05	18,000
Chute			10,050	584	36.8								
92	518.3	18,500	183,107	3,644	50.3	79.3	85.5	0.355	1:1.05	112	30	31	36	18,800
93	522.1	21,500	182,417	3,442	52.4	97.5	103.0	0.323	1:1.67	183	00	43	28	22,200
94	528.2	43,600	200,083	4,773	41.9	64.4	71.3	0.320	1:1.14	99	00	12	27	42,000
95	533.6	13,200	199,344	4,625	43.1	67.7	73.0	0.320	1:1.01	47	30	19	19	13,000
Chute, Island 93			21,667	1,080	38.7								
96	538.0	33,200	226,703	5,949	38.1	68.1	79.3	0.320	1:1.03	104	40	16	48	32,900
97	545.6	47,000	202,286	5,224	38.7	79.0	85.9	0.304	1:1.58	140	40	17	46	41,800
98	551.2	12,700	117,417	2,847	41.3	74.1	76.3	0.302	1:1.09	120	30	48	35	13,100
Chute, Island 95			80,210	2,640	36.0								

Revised table of regimen of the Mississippi River, at bank-full stage, from Cairo to the Gulf of Mexico—Continued.

Number of section.	Distance from Cairo.	Length of section.	Mean area.	Mean width.	Mean depth.	Mean thalweg depth.	Mean maximum depth.	Slope per mile, high water, 1882.	Ratio of curvature.	Curvature in degrees.				
										Total.		Per mile.		Distance on arc.
	Miles.	*Feet.*	*Sq. Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*		°	′	°	′	*Feet.*
99	553.8	14,200	174,021	3,930	44.3	83.9	89.6	0.234	1:1.03	45	10	16	55	14,100
100	558.8	38,900	156,883	4,231	37.1	80.4	85.5	0.214	1:1.49	198	55	26	27	39,700
Chute, Island 97			43,110	1,420	35.4									
101	564.5	20,580	180,850	4,337	41.8	66.1	68.6	0.214	1:1.07	42	00	11	16	19,700
102	569.4	31,080	196,100	5,631	35.9	75.8	79.3	0.214	1:1.92	170	30	31	17	28,800
103	574.4	20,620	174,769	4,113	44.2	97.6	101.3	0.214	1:1.09	80	00	20	31	20,600
104	577.5	12,440	141,125	2,900	48.9	79.5	84.2	0.214	1:1.06	86	00	36	36	12,400
Chute, Island 102			70,688	2,108	42.3									
105	581.7	32,480	188,350	4,065	47.2	73.7	75.8	0.244	1:1.08	71	00	11	34	32,400
106	587.3	26,400	153,142	3,001	53.5	77.1	79.3	0.214	1:1.21	154	55	31	56	25,600
Chute, Island 103			55,568	2,182	40.3									
107	593.4	38,160	194,071	3,625	54.1	87.2	91.2	0.214	1:1.22	137	50	19	53	36,600
108	599.4	25,206	210,233	3,847	55.3	104.6	109.7	0.311	1:1.21	195	00	40	22	25,500
109	603.8	21,120	244,653	5,979	41.2	78.6	80.9	0.403	1:1.17	122	40	30	26	21,300
110	608.2	25,520	180,903	4,174	43.6	74.6	76.5	0.406	1:1.19	131	00	27	41	25,000
111	613.7	31,780	189,022	4,970	39.7	72.4	75.6	0.277	1:2.13	172	00	37	43	24,100
112	619.0	24,080	194,393	5,146	38.6	78.3	80.4	0.307	1:1.27	124	40	28	59	22,700
113	623.1	19,840	212,044	5,218	41.9	81.8	84.9	0.391	1:1.51	161	45	43	57	19,400
114	626.9	19,840	180,277	3,884	46.8	90.6	94.7	0.436	1:1.57	192	30	49	37	20,500
115	631.3	26,780	171,581	3,921	44.5	78.3	89.4	0.476	1:1.62	195	15	36	42	28,100
116	635.5	17,660	165,000	4,376	40.4	84.5	91.3	0.549	1:1.68	173	30	52	35	17,400
117	639.2	21,620	181,198	4,025	45.9	80.9	89.8	0.561	1:1.06	93	00	21	44	22,600
118	643.6	24,980	224,696	5,083	45.2	89.2	75.9	0.117	1:1.04	34	45	7	31	24,400
119	648.0	21,120	196,090	3,833	51.6	83.4	89.2	0.128	1:1.09	76	50	19	07	21,200
120	652.5	26,400	193,045	3,644	52.5	103.2	110.1	0.400	1:1.68	200	40	38	13	27,700
121	658.5	36,960	251,632	6,106	42.7	73.2	79.8	0.164	1:1.12	127	20	17	38	38,100
122	665.0	31,680	172,494	3,819	47.3	84.5	92.5	0.264	1:1.71	175	10	28	23	32,600
Chute, Island 113			51,875	1,637	41.2									
123	671.5	36,960	194,523	3,357	60.2	94.1	103.8	0.194	1:5.60	223	00	31	14	37,700
124	679.0	42,060	237,505	4,973	48.2	89.4	97.3	0.206	1:1.31	121	15	14	55	43,000
125	686.5	37,140	209,492	4,039	52.7	86.9	96.5	0.195	1:1.37	157	50	22	26	37,800
126	693.5	36,960	198,955	4,032	50.1	94.8	105.7	0.267	1:2.87	255	05	35	00	38,500
127	698.5	15,840	211,391	3,789	56.0	115.6	135.2	0.389	1:1.23	160	30	50	10	16,000
128	702.2	23,400	183,397	2,820	65.8	82.7	88.0	0.094	1:1.03	43	00	9	53	23,000
129	707.3	29,400	233,167	4,781	50.3	70.3	73.9	0.223	1:1.05	81	40	14	40	29,400
130	712.5	26,400	224,114	5,182	45.3	75.1	80.4	0.188	1:1.16	113	00	23	13	25,700
131	717.5	26,400	193,866	3,808	62.4	103.3	110.1	0.188	1:1.63	195	35	39	40	26,000
132	723.4	36,060	237,022	6,500	36.6	76.6	85.0	0.154	1:1.70	242	30	35	33	36,000
133	731.9	53,700	197,986	3,541	57.0	93.9	102.9	0.145	1:1.74	226	45	21	58	54,500
134	739.2	23,540	194,172	3,689	54.0	96.0	110.2	0.205	1:1.44	170	50	36	59	24,400
135	743.8	24,980	209,542	3,951	53.4	95.8	106.0	0.213	1:1.16	106	10	22	30	24,900

136	750.1	41,240	202,534	3,464	59.2	97.9	109.4	0.166	1:1.11	178 15	21 24	41,500
137	755.4	12,840	232,306	3,097	75.6	133.9	149.8	0.277	1:1.41	146 40	69 37	12,000
138	759.6	33,960	226,023	3,999	57.3	86.9	99.1	0.276	1:1.01	51 40	8 04	33,800
139	767.0	43,740	217,559	3,659	60.5	85.6	98.4	0.326	1:1.41	156 20	18 35	44,400
140	773.6	25,620	192,942	3,127	63.3	102.5	116.5	0.245	1:1.14	95 15	19 43	25,500
141	778.4	25,400	215,661	4,028	56.0	78.9	85.6	0.248	1:1.01	43 55	9 12	25,200
142	782.1	14,040	211,473	3,164	67.5	118.9	120.9	0.209	1:1.23	114 30	44 13	13,700
143	787.1	38,080	203,999	3,348	61.6	105.3	129.5	0.284	1:1.91	225 35	30 32	39,000
144	792.3	17,520	205,267	3,665	57.5	106.9	123.0	0.062	1:1.04	61 40	18 24	17,700
145	796.0	21,120	192,007	2,953	65.4	108.7	127.7	0.251	1:1.04	61 00	15 10	21,200
146	802.0	41,340	191,345	3,271	61.4	86.9	97.4	0.196	1:1.27	118 30	14 48	42,300
147	807.5	17,460	191,388	3,266	59.1	93.8	107.4	0.323	1:1.21	115 00	85 16	17,200
148	810.4	13,720	205,429	2,891	71.2	111.9	128.6	0.331	1:1.20	142 30	50 11	15,000
149	814.9	33,080	177,396	3,624	50.0	82.1	96.9	0.134	1:1.31	158 45	24 48	33,800
Chute, Profit Island			38,400	1,080	45.9							
150	819.5	16,360	190,088	3,404	56.1	96.6	116.5	0.175	1:1.27	122 30	37 35	17,200
151	823.1	21,100	186,019	2,948	63.3	115.2	133.2	0.189	1:1.88	179 50	44 44	21,200
152	826.5	14,440	172,719	2,460	70.8	94.2	105.7	0.233	1:1.02	23 30	8 33	14,500
153	828.5	7,460	230,482	2,620	87.5	131.8	143.1	0.240	1:1.17	122 00	82 26	7,800
154	831.7	26,520	177,895	2,651	67.6	99.8	103.4	0.264	1:1.00	0 00	0 00	26,500
155	836.0	18,320	180,011	2,884	63.2	98.1	106.6	0.146	1:1.03	50 20	14 25	18,400
156	840.9	33,080	191,136	3,186	61.0	94.1	113.1	0.236	1:1.78	167 35	26 21	33,600
157	847.2	33,780	191,380	2,850	67.7	101.2	115.1	0.189	1:2.79	186 25	27 49	35,400
158	853.7	35,280	181,988	2,779	66.6	102.3	125.6	0.089	1:2.80	206 55	30 47	35,500
159	858.7	17,620	192,000	3,224	61.1	92.4	107.4	0.158	1:1.01	48 15	13 59	18,200
160	863.0	27,480	192,844	2,622	74.7	102.6	123.5	0.218	1:1.37	122 00	23 01	28,000
161	868.5	30,780	199,017	2,929	70.9	108.3	128.8	0.198	1:2.08	190 10	31 58	31,400
162	874.3	30,420	186,950	3,077	62.5	98.3	112.5	0.102	1:1.11	89 40	15 28	30,600
163	879.7	26,540	200,433	2,965	69.4	101.2	116.0	0.168	1:1.23	108 40	20 37	27,800
164	883.6	14,580	202,125	2,633	77.6	113.8	136.0	0.186	1:1.63	169 00	63 18	14,100
165	886.8	19,180	213,491	3,346	64.8	99.7	115.1	0.168	1:1.10	129 30	35 23	19,300
166	890.7	21,580	200,492	2,359	85.3	122.6	142.9	0.164	1:2.05	201 15	46 22	22,900
167	895.2	26,400	177,056	2,170	81.9	114.5	137.0	0.163	1:1.24	114 00	21 54	27,500
168	899.9	22,600	176,645	2,285	77.9	106.4	123.7	0.163	1:1.16	112 20	25 41	23,100
169	904.5	26,800	186,191	2,564	73.2	100.3	112.5	0.108	1:1.78	140 10	26 27	28,000
170	908.8	18,740	178,723	2,407	74.7	100.0	112.7	0.190	1:1.07	125 50	34 57	19,100
171	912.3	17,820	188,527	2,331	81.1	104.1	111.1	0.090	1:1.01	24 10	7 05	18,000
172	915.7	17,820	177,217	2,406	74.0	96.4	108.3	0.200	1:1.29	123 30	35 30	18,400
173	918.4	11,360	212,042	2,450	86.8	113.4	125.6	0.244	1:1.27	117 00	55 27	11,200
174	921.3	18,340	172,205	2,255	76.5	101.1	115.3	0.080	1:1.03	52 00	14 50	18,500
175	924.3	13,840	157,432	2,006	78.6	104.4	117.8	0.013	1:1.05	75 40	28 33	14,000
176	927.5	20,120	181,500	3,136	59.2	88.2	96.6	0.411	1:1.49	150 50	39 23	20,200
177	931.9	26,120	166,521	2,416	68.3	100.3	115.1	0.149	1:1.19	117 20	23 28	26,400
178	935.8	14,740	156,694	2,741	58.3	85.8	99.7	0.238	1:1.18	113 10	39 34	15,100
179	940.7	37,560	182,902	2,345	77.0	105.5	116.7	0.127	1:1.15	167 00	23 12	38,000
180	947.3	31,980	163,276	2,490	66.4	96.2	110.0	0.206	1:1.30	150 10	24 01	33,000
181	952.3	20,420	170,382	2,521	69.2	98.1	109.4	0.102	1:1.42	133 10	32 43	21,500
182	956.1	19,920	183,603	2,582	72.1	100.1	118.6	0.164	1:1.76	158 20	38 54	21,500
183	960.2	23,320	179,414	2,463	74.3	100.7	114.3		1:3.22	136 50	28 59	24,900
184	964.0	17,420	172,327	2,052	84.0	102.9	115.4		1:1.15	102 00	30 49	17,500
185	967.9	22,920	195,138	2,287	86.7	107.3	120.8		1:1.22	155 40	33 59	24,200
186	971.6	16,440	158,639	2,391	66.6	89.3	97.3		1:1.02	56 30	18 24	16,200

Revised table of regimen of the Mississippi River, at bank-full stage, from Cairo to the Gulf of Mexico—Continued.

Number of section.	Distance from Cairo.	Length of section.	Mean area.	Mean width.	Mean depth.	Mean thalweg depth.	Mean maximum depth.	Slope per mile, high water, 1882.	Ratio of curvature.	Curvature in degrees.				
										Total.		Per mile.		Distance on arc.
	Miles.	*Feet.*	*Sq. Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*		°	′	°	′	*Feet.*
187	977.3	43,920	164,794	2,399	69.1	93.2	104.0	.....	1:2.73	228	10	26	36	45,300
188	983.2	18,640	173,271	2,249	77.3	103.0	114.8	.....	1:1.21	191	10	50	35	19,900
189	987.0	21,120	143,769	2,288	63.1	86.7	109.4	.....	1:1.02	86	30	21	28	21,300
190	991.6	27,300	144,910	2,387	61.1	84.7	96.7	.....	1:1.13	112	00	21	45	27,200
191	996.7	26,620	151,387	2,192	68.4	90.5	102.7	.....	1:1.03	116	10	22	44	27,000
192	1,001.0	19,000	173,175	2,444	71.6	103.5	117.9	.....	1:1.07	104	30	29	02	19,000
193	1,004.9	21,840	145,385	2,368	61.5	84.8	96.1	.....	1:1.01	33	30	8	02	22,000
194	1,009.2	23,900	146,509	2,471	59.9	86.4	101.8	.....	1:1.02	72	10	15	56	24,000
195	1,015.0	37,060	163,114	2,600	64.6	92.4	110.0	.....	1:1.04	167	40	23	33	37,600
196	1,021.2	28,580	145,808	2,298	63.8	89.9	103.7	.....	1:1.07	77	10	13	54	29,300
197	1,025.8	20,120	164,056	2,302	72.4	103.9	117.0	.....	1:1.19	114	40	29	28	20,500
198	1,030.8	32,580	151,740	2,438	62.4	89.9	104.5	.....	1:1.11	93	30	14	49	33,300
199	1,035.2	13,860	109,750	2,702	62.6	96.3	107.7	.....	1:1.01	27	30	10	08	14,100
200	1,037.6	11,360	180,819	2,206	83.4	116.4	131.9	.....	1:1.13	104	30	43	22	12,700
201	1,040.6	20,320	191,020	2,480	78.4	109.6	125.8	.....	1:1.12	101	30	25	38	20,900
202	1,044.1	17,020	154,486	2,512	61.5	80.9	86.6	.....	1:1.01	28	00	8	35	17,200
203	1,048.2	26,020	161,000	2,680	60.1	83.6	92.3	.....	1:1.02	30	00	5	58	26,500
204	1,053.3	27,180	163,500	3,350	50.0	69.8	79.8	.....	1:1.03	37	00	7	06	27,500
205	1,057.6	18,640	175,960	5,801	31.2	42.4	44.6	.....	1:1.03	27	00	7	55	18,000
South West Pass	1,066.5	75,900	63,170	1,388	45.9	60.5	67.9	.....	1:1.01	60	30	4	13	75,900
Pass à l'Outre	1,064.3	26,400	70,192	2,144	34.3	50.0	59.9	.....	1:1.05	105	30	21	06	26,400
South Pass	1,065.0	60,720	19,855	683	29.4	33.0	42.3	.....	1:1.03	109	30	9	30	60,720

Mean regimen elements of the Mississippi River, bank-full stage; Cairo to the Head of the Passes.

From—	To—	Distance from Cairo.	Mean water area of cross-section.	Mean width.	Mean depth.	Mean thalweg depth.	Mean maximum depth.	Mean curvature per mile.
		Miles.	*Sq. ft.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	° ′
Cairo	New Madrid	65.3	214,022	5,512	55.5	66.4	75.0	21 32
New Madrid	Plum Point	160.8	210,745	5,712	50.2	61.8	67.7	24 34
Plum Point	Memphis	231.0	199,894	5,682	60.9	66.1	73.9	26 33
Memphis	Helena	302.2	195,831	5,876	37.6	57.5	63.2	28 07
Helena	Arkansas River	398.3	190,746	4,563	55.4	74.3	81.2	24 44
Arkansas River	Greenville	476.3	196,901	4,555	53.1	81.2	86.1	27 04
Greenville	Lake Providence	538.0	192,720	4,758	51.5	73.8	81.6	22 01
Lake Providence	Vicksburg	599.4	194,954	4,675	58.0	81.6	85.6	26 06
Vicksburg	Natchez	698.5	203,356	4,526	49.0	85.0	91.7	31 16
Natchez	Red River	759.6	212,192	4,030	56.1	92.0	101.3	26 41
Red River	Baton Rouge	831.7	199,960	3,260	66.5	100.3	114.6	28 23
Baton Rouge	New Orleans	967.9	184,189	2,605	72.4	101.5	116.9	29 31
New Orleans	Head of Passes	1,057.6	161,155	2,628	64.4	90.3	101.8	20 15

ADDITIONAL REPORT OF ASSISTANT ENGINEER L. C. JONES.

CAPTAIN: I have the honor to submit herewith my report upon the "table of means," which was begun in February, 1884, in accordance with instructions from Lieut. Smith S. Leach, who furnished me with the following resolution of the committee on surveys and examinations, November 19, 1883:

"That the secretary furnish for the use of the committee a table showing the mean width, mean depth, and mean channel depths for each 2 miles of river at a medium stage of water."

The stage of water selected by me was that of mean stage for the year 1882, there being full data at all the principal gauges.

From the data I obtained the general slope per mile at medium stage between gauges, and could by this means compute the elevation of mean stage for any given section.

Having already computed and plotted the cross-sections for bank-full stage for the "high-water regimen," the cross-sections at medium stage could be determined by simple subtraction.

When the work had been finished to Memphis I received orders to extend the "table of means" by showing the same elements of cross-sections at a bank-full stage, and in this portion of the work used the cross-sections as measured for the "high-water regimen."

The planimeter was used to measure the cross-section area, which, divided by the width, gave the mean depth. The width and channel depth were measured with a scale.

The river was divided into 2-mile divisions, the upper end of the first division being 2 miles below Cairo, the origin of distance.

The means of the three elements, in all the cross-sections embraced in each 2 miles, were taken, and are the values given in the tabulation. New values for the means were obtained from the new surveys, and extend from Cairo to Old Hen Island from Commerce Cut-off to St. Louis Landing, Arkansas.

Very respectfully, your obedient servant,

L. C. JONES,
Assistant Engineer.

To Capt. THOMAS TURTLE,
Corps of Engineers, U. S. A.,
Secretary Mississippi River Commission.

Mean widths, mean depths, and means of maximum depths of 2-mile sections of main river from Cairo, Illinois, to Head of Passes.

No. of section.	Distance from Cairo.	Medium stage.			Bank-full stage.		
		Mean width.	Mean depth.	Mean of maximum depth.	Mean width.	Mean depth.	Mean of maximum depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1							
2							
3							
4							
5	10	4,707	29.8	59.1	4,826	42.2	70.2
6	12	4,380	30.1	58.8	4,874	40.6	71.7
7	14	5,138	22.9	73.2	7,257	30.1	86.9
8	16	3,968	31.8	63.1	4,161	44.5	76.9
9	18	3,518	38.7	56.2	3,660	50.6	69.2
10	20	2,694	61.3	101.4	2,830	71.4	115.0
11	22	6,008	26.2	62.2	6,110	39.0	75.2
12	24	4,221	30.6	53.0	4,353	42.7	66.0
13	26	4,281	27.9	46.4	4,577	39.5	59.3
14	28	4,598	32.1	48.3	4,755	42.3	59.4
15	30	5,996	26.3	62.2	6,172	37.6	74.2
16	32	4,789	31.2	63.3	5,274	40.4	75.9
17	34	4,845	28.2	94.9	4,944	40.9	106.2
18	36	2,800	49.8	81.9	3,625	50.9	94.9
19	38	4,522	37.2	59.3	4,609	48.7	62.6
20	40	4,788	32.7	62.2	4,860	43.8	74.6
21	42	4,688	31.3	55.6	4,768	43.1	65.4
22	44	4,301	30.8	56.3	4,404	43.7	69.8
23	46	4,289	26.9	74.8	4,473	37.8	86.0
24	48	2,933	40.2	72.9	3,074	49.7	83.8
25	50	4,043	35.4	57.4	4,094	46.2	68.7
26	52	5,843	28.6	44.8	5,794	41.0	56.6
27	54	4,920	31.9	64.3	5,063	42.8	76.2
28	56	4,646	31.1	64.5	4,841	42.3	76.5
29	58	7,170	22.5	48.5	9,795	28.9	61.1
30	60	5,058	28.5	56.5	7,280	31.2	68.0
31	62	4,819	28.6	55.6	5,547	37.5	67.3
32	64	4,431	22.4	65.9	5,788	33.3	77.2
33	66	5,060	29.1	51.9	5,834	38.5	62.6
34	68	5,694	25.2	53.5	6,620	33.2	63.9
35	70	4,932	25.7	65.8	5,045	39.4	77.3
36	72	5,779	27.7	42.7	6,057	37.4	55.1
37	74	5,828	24.5	47.0	5,988	38.2	60.5
38	76	7,061	21.4	39.3	7,748	34.7	53.7
39	78	7,319	24.2	47.0	7,499	39.7	62.4
40	80	4,583	29.1	73.8	5,847	37.4	89.5
41	82	4,271	32.1	54.3	4,849	44.5	70.9
42	84	5,657	25.5	46.8	5,873	41.5	63.2
43	86	4,294	29.6	56.6	4,711	41.5	71.1
44	88	5,011	28.2	50.7	6,527	35.8	64.1
45	90	4,080	29.1	65.5	7,550	30.1	83.1
46	92	3,106	37.3	70.5	6,108	32.6	83.9
47	94	4,018	34.2	56.0	4,678	42.6	73.0
48	96	5,290	25.8	56.4	5,397	40.5	72.3
49	98	4,823	27.9	55.6	5,337	40.6	70.2
50	100	4,611	29.1	51.8	4,804	43.6	65.7
51	102	4,398	29.4	60.4	4,605	43.1	69.9
52	104	3,290	33.9	75.3	6,095	31.5	89.4
53	106	2,938	40.3	70.3	4,975	38.2	84.0
54	108	3,998	33.2	50.7	4,129	45.0	62.4
55	110	4,521	30.2	47.3	4,579	42.8	59.9
56	112	5,523	25.6	43.7	5,694	39.6	57.5
57	114	5,092	26.3	55.2	5,156	40.5	68.7
58	116	3,873	32.0	58.3	3,965	46.5	72.3
59	118	5,173	26.9	45.1	5,139	41.7	60.3
60	120	2,510	28.2	50.3	3,207	41.9	63.9
61	122	4,996	28.0	43.4	5,100	43.5	60.2
62	124	4,858	22.5	53.0	5,644	35.2	69.1
63	126	3,705	29.9	47.8	3,990	45.2	64.8
64	128	4,404	26.9	36.6	4,465	43.6	52.8
65	130	4,785	25.1	46.5	4,942	40.7	62.2
66	132	3,970	29.6	52.1	4,272	43.6	67.5
67	134	4,080	30.0	57.3	5,087	41.0	73.3
68	136	3,577	28.5	64.4	5,709	32.5	79.8
69	138	3,232	35.5	56.7	3,904	45.3	71.8
70	140	4,160	24.5	63.1	4,864	35.6	78.1
71	142	3,002	34.9	63.6	4,020	40.4	78.3
72	144	4,016	27.8	46.9	4,141	44.3	62.8
73	146	3,075	28.8	55.8	4,006	38.4	71.8

Mean widths, mean depths, and means of maximum depths of 2-mile sections of main river from Cairo, Illinois, to Head of Passes—Continued.

No. of section.	Distance from Cairo.	Medium stage.			Bank-full stage.		
		Mean width	Mean depth.	Mean of maximum depth.	Mean width.	Mean depth.	Mean of maximum depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
74	148	4,380	24.1	50.0	4,960	37.5	65.9
75	150	2,611	31.2	56.1	4,286	31.5	70.9
76	152	4,312	24.7	50.6	5,306	34.7	64.9
77	154	3,913	27.1	51.9	4,019	41.5	66.0
78	156	5,145	24.8	38.4	5,859	38.4	53.2
79	158	6,149	17.9	40.1	8,167	29.0	55.1
80	160	5,971	20.3	38.7	6,736	33.4	58.7
81	162	6,726	19.6	44.7	7,710	32.1	50.8
82	164	5,302	24.0	42.8	4,326	43.1	59.0
83	166	7,924	17.9	34.8	7,191	31.8	50.1
84	168	4,896	26.4	49.9	6,864	33.6	66.3
85	170	4,164	31.5	49.4	5,920	39.2	66.1
86	172	2,959	47.4	84.3	3,353	59.4	101.0
87	174	2,651	46.0	60.8	2,813	60.7	77.8
88	176	4,688	26.3	38.1	5,044	43.8	55.8
89	178	5,033	24.8	40.7	5,625	42.2	57.6
90	180	4,948	26.1	46.7	5,046	43.8	63.7
91	182	3,701	37.4	84.0	4,037	51.1	101.6
92	184	2,335	55.2	89.4	2,539	69.3	107.5
93	186	3,264	27.9	61.3	3,981	40.9	78.4
94	188	4,130	22.9	49.3	4,376	37.2	64.5
95	190	4,693	18.6	51.5	5,454	32.6	67.6
96	192	2,993	28.3	51.2	4,248	34.7	67.8
97	194	3,380	26.9	45.1	3,653	42.8	62.1
98	196	3,793	29.4	53.5	4,218	44.2	72.2
99	198	4,502	26.6	52.9	4,713	45.1	71.5
100	200	4,693	25.2	58.4	5,548	38.5	75.8
101	202	3,266	31.9	62.3	3,908	41.8	77.8
102	204	3,067	29.2	57.5	3,722	40.1	73.7
103	206	4,109	25.1	42.6	4,245	40.6	58.4
104	208	1,971	51.6	90.2	2,097	64.1	90.8
105	210	3,586	38.4	77.8	4,084	47.5	84.2
106	212	6,519	17.1	41.7	6,872	30.1	56.3
107	214	5,313	21.6	46.0	6,907	31.8	60.9
108	216	2,986	28.3	54.1	6,638	26.2	69.3
109	218	3,373	27.0	55.2	4,862	35.8	71.0
110	220	4,089	28.2	50.8	4,200	43.9	66.6
111	222	4,836	24.9	60.5	5,586	36.1	75.4
112	224	4,085	32.4	58.0	4,540	41.3	62.9
113	226	3,278	36.6	81.0	4,750	34.1	76.8
114	228	2,650	41.0	69.2	3,285	45.7	79.2
115	230	2,793	38.9	79.3	2,995	44.7	88.9
116	232	4,070	27.4	46.3	4,327	33.9	56.8
117	234	3,553	17.4	38.7	5,540	23.5	51.0
118	236	4,127	16.3	36.3	4,950	28.2	48.3
119	238	3,653	20.2	38.0	3,800	32.5	50.5
120	240	4,912	22.2	39.0	5,192	35.0	51.5
121	242	5,397	23.9	40.7	5,467	37.8	52.3
122	244	4,930	23.7	41.7	5,078	36.1	53.8
123	246	4,378	27.3	46.5	4,962	36.1	60.2
124	248	4,667	21.8	47.0	6,410	29.5	60.3
125	250	2,470	33.0	46.8	3,565	37.9	61.9
126	252	3,408	29.0	43.0	3,555	43.1	58.7
127	254	5,137	20.2	37.3	5,313	35.9	53.8
128	256	3,673	24.2	37.7	4,123	32.8	50.6
129	258	4,698	24.3	35.8	5,005	35.2	48.3
130	260	3,780	20.0	33.0	3,953	32.5	46.7
131	262	3,733	22.0	33.0	4,737	27.9	42.7
132	264	3,893	21.5	32.0	5,383	25.5	42.1
133	266	3,807	20.2	32.0	5,387	25.4	43.4
134	268	5,007	22.4	36.7	6,177	30.1	49.0
135	270	6,447	21.2	52.0	7,220	31.4	64.2
136	272	6,047	21.5	57.7	8,253	24.7	67.7
137	274	4,000	32.2	66.6	5,140	37.1	79.4
138	276	3,922	25.1	69.8	8,349	24.6	83.7
139	278	4,110	27.8	52.5	5,902	33.5	67.2
140	280	3,781	31.1	59.8	4,204	39.5	73.0
141	282	5,286	25.8	51.0	5,598	37.7	64.0
142	284	4,384	28.5	62.6	4,812	39.8	75.6
143	286	2,999	36.7	71.6	4,330	38.6	85.4
144	288	6,041	23.1	47.9	6,640	35.4	61.9
145	290	3,866	29.2	61.8	4,703	39.2	76.2
146	292	5,730	25.9	52.0	5,783	41.9	66.3

Mean widths, mean depths, and means of maximum depths of 2-mile sections of main river from Cairo, Illinois, to Head of Passes—Continued.

No. of section.	Distance from Cairo.	Medium stage.			Bank-full stage.		
		Mean width.	Mean depth.	Mean of maximum depth.	Mean width.	Mean depth.	Mean of maximum depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
147	294	6,806	20.4	52.8	7,322	34.4	68.2
148	296	4,567	28.1	59.5	6,248	35.8	74.6
149	298	4,272	32.3	68.8	4,496	47.6	84.5
150	300	4,834	34.3	54.3	4,586	50.7	70.0
151	302	7,589	19.8	58.4	9,256	32.0	75.3
152	304	4,051	33.3	78.7	5,387	42.0	93.6
153	306	4,653	29.5	61.5	4,865	45.1	77.0
154	308	4,829	27.8	60.9	5,417	40.7	76.2
155	310	3,806	37.9	63.8	4,629	46.4	71.6
156	312	6,418	25.3	61.5	7,398	35.2	85.0
157	314	3,153	42.0	94.2	4,175	45.3	108.8
158	316	5,034	30.7	52.9	5,135	46.1	68.3
159	318	3,834	35.2	74.1	4,154	45.8	76.6
160	320	3,515	39.2	62.9	3,836	49.1	76.0
161	322	3,241	37.6	71.7	3,528	48.2	84.9
162	324	2,820	41.6	95.2	3,619	45.4	107.7
163	326	3,152	37.2	83.3	3,513	45.4	95.8
164	328	4,246	28.8	55.8	4,802	42.6	69.1
165	330	5,475	19.1	65.4	6,087	31.2	79.6
166	332	3,421	32.6	66.0	3,790	43.9	78.1
167	334	4,486	30.8	56.6	4,580	44.1	69.9
168	336	3,959	30.6	60.7	4,070	43.7	74.7
169	338	3,398	36.8	75.0	3,671	49.2	88.9
170	340	3,636	32.8	73.8	4,171	41.4	86.8
171	342	4,987	29.7	65.5	6,027	37.8	78.6
172	344	3,677	32.7	78.0	5,234	32.8	89.9
173	346	2,977	36.6	74.5	4,454	36.6	88.1
174	348	3,137	35.6	56.3	3,225	46.4	67.7
175	350	4,488	25.6	65.2	4,544	35.8	75.6
176	352	3,583	28.1	63.3	3,890	37.4	75.0
177	354	2,908	34.9	70.0	3,110	44.4	81.9
178	356	3,140	39.3	61.0	3,188	51.7	73.3
179	358	4,188	32.2	53.6	4,282	44.9	67.0
180	360	5,430	25.8	51.4	5,104	37.6	64.8
181	362	2,680	24.1	63.2	3,392	39.2	76.0
182	364	2,452	39.1	67.2	2,716	52.0	80.8
183	366	3,756	33.6	51.4	3,818	48.3	66.4
184	368	4,002	28.7	55.8	4,088	44.3	72.1
185	370	3,510	32.1	69.0	3,658	43.9	82.3
186	372	2,514	47.5	90.4	2,902	53.7	103.9
187	374	3,324	34.4	86.0	3,816	43.7	100.1
188	376	3,548	38.1	65.0	3,888	49.5	80.4
189	378	4,194	28.2	72.6	6,010	36.2	90.8
190	380	2,818	41.2	68.6	3,264	49.7	83.8
191	382	4,390	29.5	50.4	4,836	40.6	64.2
192	384	4,493	28.6	53.5	4,925	39.7	66.8
193	386	2,715	38.4	79.2	3,113	46.7	93.5
194	388	2,935	42.2	59.5	3,042	54.2	74.0
195	390	4,572	28.4	64.0	4,704	42.5	79.1
196	392	3,497	37.6	69.5	3,808	47.0	84.5
197	394	2,612	46.8	86.0	3,662	47.7	101.5
198	396	3,410	40.4	64.5	3,900	50.9	80.7
199	398	3,998	33.4	65.0	4,415	47.2	80.8
200	400	3,158	42.1	70.2	3,282	54.5	83.3
201	402	3,432	36.4	67.5	3,675	45.4	81.2
202	404	3,330	40.3	79.2	4,032	44.5	95.0
203	406	3,410	48.0	93.2	3,944	56.4	108.5
204	408	2,154	55.4	99.6	3,906	42.1	114.1
205	410	2,984	41.7	66.8	3,674	47.4	80.1
206	412	4,015	33.4	55.5	4,152	48.1	70.5
207	414	3,788	29.3	54.4	5,094	33.3	68.0
208	416	2,407	47.3	89.3	4,007	40.1	102.6
209	418	3,597	38.8	62.0	3,982	51.1	75.4
210	420	4,848	29.2	65.7	5,318	38.9	78.3
211	422	4,256	33.1	70.8	4,282	47.1	85.9
212	424	5,280	26.6	89.6	5,932	37.6	104.7
213	426	3,272	38.3	86.2	3,966	45.5	100.7
214	428	3,040	43.6	92.8	3,302	55.1	107.8
215	430	3,090	44.3	69.2	3,322	56.8	85.6
216	432	4,267	34.4	54.3	4,660	47.0	69.5
217	434	5,845	26.4	48.5	7,862	32.9	58.4
218	436	3,496	43.3	77.2	3,694	55.9	92.9
219	438	3,458	47.7	80.6	3,610	60.6	95.9
220	440	2,573	51.4	95.0	3,627	59.7	111.0

Mean widths, mean depths, and means of maximum depths of 2-mile sections of main river from Cairo, Illinois, to Head of Passes—Continued.

No. of section.	Distance from Cairo.	Medium stage.			Bank-full stage.		
		Mean width.	Mean depth.	Mean of maximum depth.	Mean width.	Mean depth.	Mean of maximum depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
221	442	2,467	51.7	78.7	2,817	60.8	94.6
222	444	3,412	30.1	61.5	6,623	30.3	78.3
223	446	4,111	31.8	57.9	4,660	45.1	75.7
224	448	3,813	38.2	75.0	4,396	50.5	93.3
225	450	2,961	40.4	84.7	3,674	48.4	100.4
226	452	2,554	46.5	77.4	2,814	57.7	94.7
227	454	3,520	36.7	58.7	3,924	48.7	75.0
228	456	4,046	29.4	65.4	5,183	39.8	83.0
229	458	3,400	34.1	76.4	3,713	49.1	94.6
230	460	3,399	35.8	72.0	3,858	46.0	87.6
231	462	3,365	37.3	61.3	3,542	49.6	75.4
232	464	4,723	29.6	61.4	4,789	47.1	79.3
233	466	4,562	28.2	74.5	5,243	40.6	90.7
234	468	2,649	44.2	81.9	3,053	56.3	100.2
235	470	2,687	42.6	73.4	3,237	52.4	91.5
236	472	3,477	36.1	49.5	3,618	53.2	67.5
237	474	4,184	26.4	64.1	4,584	40.3	80.4
238	476	3,878	29.6	65.3	4,947	39.2	82.4
239	478	3,584	34.3	59.0	4,150	45.5	76.0
240	480	3,905	33.1	49.5	4,487	43.4	64.0
241	482	5,417	27.7	50.3	5,493	46.1	68.5
242	484	4,755	55.9	57.0	4,970	40.7	72.5
243	486	5,446	24.8	43.8	6,124	37.9	60.6
244	488	4,102	29.2	58.7	5,078	41.8	72.0
245	490	3,847	31.8	57.5	4,135	47.8	75.5
246	492	3,380	35.2	58.6	4,920	40.4	57.5
247	494	3,240	43.8	71.2	3,885	54.3	89.2
248	496	2,443	44.9	78.0	3,640	47.2	95.8
249	498	3,373	33.9	72.2	4,447	38.7	86.3
250	500	4,077	30.3	57.0	4,447	42.2	72.0
251	502	4,140	30.4	49.7	4,237	45.6	65.8
252	504	4,157	27.4	50.2	5,212	38.0	72.4
253	506	3,473	30.9	65.7	5,727	32.6	81.6
254	508	2,998	35.6	84.3	5,220	33.8	96.3
255	510	3,706	33.4	70.2	3,826	46.6	84.8
256	512	4,015	32.4	62.0	5,100	40.8	27.0
257	514	3,682	32.5	56.7	4,865	39.0	70.9
258	516	3,615	34.0	68.0	3,998	46.0	79.8
259	518	3,254	38.3	72.2	3,798	47.4	86.9
260	520	3,360	44.4	91.7	3,540	56.4	106.5
261	522	2,873	43.4	97.7	3,313	52.9	112.4
262	524	3,992	31.1	50.0	4,055	46.6	66.1
263	526	4,617	27.8	57.5	4,762	42.8	73.3
264	528	4,823	29.6	47.7	5,713	37.5	61.7
265	530	3,908	36.9	65.0	4,507	43.3	79.2
266	532	4,750	29.2	54.3	5,128	41.5	68.7
267	534	4,423	30.8	62.7	4,500	45.7	78.0
268	536	4,220	29.5	80.7	5,070	38.7	95.7
269	538	6,250	24.1	46.0	7,173	36.6	62.3
270	540	4,550	29.4	63.8	5,580	38.5	79.6
271	542	4,365	29.4	77.8	5,012	40.9	76.7
272	544	5,725	25.5	49.5	6,255	32.7	64.5
273	246	5,575	24.5	67.0	7,330	30.3	77.7
274	248	3,554	36.4	80.4	4,340	44.1	95.0
275	550	2,225	40.4	66.0	2,918	41.8	79.5
276	552	2,596	42.7	78.2	2,964	50.9	92.6
277	554	3,630	33.1	64.5	4,658	40.4	78.7
278	556	3,976	29.1	48.2	4,926	37.2	63.5
279	558	2,910	35.5	75.6	4,476	38.1	91.5
280	560	2,107	41.9	91.0	3,553	37.4	105.0
281	562	2,473	43.9	79.5	3,479	42.4	86.0
282	564	4,026	29.2	48.0	4,436	40.5	62.7
283	566	4,820	25.0	51.8	5,408	38.2	70.0
284	568	5,012	22.9	57.5	7,040	31.9	74.3
285	570	4,180	27.0	67.0	5,580	34.4	81.9
286	572	3,158	39.7	75.4	3,630	50.4	91.4
287	574	2,510	45.9	97.6	4,264	39.7	112.1
288	576	3,120	32.6	64.3	3,445	45.1	79.5
289	578	2,353	48.3	79.0	2,817	51.6	91.8
290	580	4,488	31.6	61.4	4,634	44.2	76.3
291	582	4,006	30.7	52.6	4,274	45.9	69.9
292	584	3,427	37.4	46.8	3,505	47.3	65.0
293	586	3,451	37.6	64.1	3,738	47.6	76.6
294	588	1,812	53.4	74.5	1,810	67.6	88.9

Mean widths, mean depths, and means of maximum depths of 2-mile sections of main river from Cairo, Illinois, to Head of Passes—Continued.

No. of section.	Distance from Cairo.	Medium stage.			Bank-full stage.		
		Mean width.	Mean depth.	Mean of maximum depth.	Mean width.	Mean depth.	Mean of maximum depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
295	590	3,416	40.4	72.6	3,470	54.5	87.7
296	592	2,996	40.0	93.0	3,490	50.9	108.4
297	594	3,532	43.1	73.3	3,615	58.5	89.7
298	596	3,560	39.0	78.8	3,807	51.8	94.2
299	598	3,138	52.5	108.3	3,807	60.8	120.8
300	600	3,645	41.4	73.0	4,108	48.7	86.1
301	602	3,665	30.6	85.8	5,705	36.4	99.6
302	604	5,722	31.9	52.2	6,198	45.0	66.4
303	606	3,223	34.9	64.7	4,630	40.7	81.0
304	608	3,626	31.8	61.0	4,172	42.9	76.1
305	610	3,826	34.7	58.8	4,258	45.3	74.5
306	612	3,790	24.4	60.4	5,210	38.7	74.2
307	614	3,510	33.9	62.7	5,260	35.2	76.6
308	616	3,860	36.0	64.2	4,140	49.8	77.2
309	618	3,650	33.7	69.8	5,390	36.1	85.1
310	620	3,330	38.4	63.9	4,900	42.3	78.6
311	622	5,240	26.6	68.3	5,820	40.0	84.5
312	624	3,710	38.8	77.7	4,810	44.2	93.8
313	626	2,860	42.5	79.1	3,770	44.1	91.6
314	628	3,290	42.7	71.0	3,720	51.8	85.0
315	630	3,040	38.3	69.6	3,950	39.9	82.9
316	632	3,920	31.9	77.0	4,330	39.0	87.3
317	634	3,160	42.3	81.2	4,410	41.3	91.9
318	636	3,870	37.7	71.7	4,570	42.5	83.1
319	638	3,480	31.5	81.3	3,940	41.3	94.8
320	640	3,660	39.6	69.8	3,970	49.7	84.1
321	642	5,470	27.8	67.8	6,110	39.8	84.3
322	644	4,150	35.7	53.6	4,220	48.6	67.0
323	646	3,730	38.7	53.7	3,860	52.4	68.2
324	648	3,130	45.6	99.8	3,800	50.6	113.8
325	650	3,400	48.8	88.8	3,890	57.1	103.8
326	652	2,430	51.9	103.9	3,400	49.1	118.4
327	654	3,790	40.9	74.6	4,130	52.1	91.1
328	656	7,870	21.3	70.6	7,940	37.4	87.2
329	658	5,350	29.5	64.0	5,760	43.8	80.1
330	660	4,160	31.8	56.7	4,980	43.4	72.9
331	662	4,970	26.7	72.4	5,660	38.0	87.2
332	664	3,040	37.5	78.6	3,730	42.7	92.6
333	666	2,460	46.0	83.2	2,660	56.8	35.2
334	668	4,120	36.7	66.4	4,210	51.9	82.2
335	670	3,440	44.9	90.6	3,470	59.8	105.9
336	672	2,300	57.3	108.1	2,420	69.4	123.2
337	674	3,850	44.8	81.7	3,940	58.6	98.9
338	676	4,820	32.6	83.2	4,890	50.0	96.9
339	678	5,960	31.3	68.8	6,090	46.1	84.6
340	680	4,060	36.4	87.8	4,680	43.5	101.4
341	682	3,760	41.4	88.5	4,350	50.7	103.9
342	684	3,590	41.1	62.9	3,760	55.5	79.2
343	686	4,380	33.0	94.6	4,570	46.6	111.3
344	688	3,080	50.7	91.8	3,720	56.2	107.1
345	690	3,710	40.0	79.7	3,990	52.0	94.4
346	692	2,760	45.7	99.6	4,360	42.4	113.5
347	694	3,350	44.3	92.8	3,920	50.8	106.4
348	696	2,990	55.8	111.7	3,710	61.6	128.8
349	698	2,580	54.8	119.2	3,800	53.7	137.1
350	700	2,360	56.5	90.0	2,510	71.8	108.3
351	702	2,890	44.8	57.3	2,970	62.4	76.0
352	704	4,420	33.5	58.9	4,660	51.0	77.8
353	706	5,310	28.2	49.6	5,460	45.5	68.1
354	708	3,710	38.7	59.4	3,780	56.3	78.0
355	710	5,530	28.2	55.6	5,860	42.8	72.1
356	712	5,330	27.8	64.0	5,940	41.9	78.8
357	714	2,430	60.3	98.8	2,630	71.2	113.9
358	716	2,490	52.7	106.0	3,010	59.9	121.7
359	718	3,240	39.4	73.9	4,270	53.5	89.3
360	720	3,320	36.7	73.3	6,170	38.9	89.9
361	722	3,950	31.5	63.6	7,400	37.3	79.6
362	724	3,330	37.6	67.9	6,130	34.6	82.1
363	726	2,340	56.7	100.5	3,420	58.6	115.8
364	728	3,660	37.8	99.6	3,850	52.2	117.8
365	730	4,350	32.4	72.7	4,580	47.8	89.9
366	732	2,960	47.9	96.7	3,250	59.4	113.4
367	734	3,080	44.6	77.1	3,260	58.8	98.9
368	736	3,330	44.1	61.7	3,490	59.5	78.6

Mean widths, mean depths, and means of maximum depths of 2-mile sections of main river from Cairo, Illinois, to Head of Passes—Continued.

No. of section.	Distance from Cairo.	Medium stage.			Bank-full stage.		
		Mean width.	Mean depth.	Mean of maximum depth.	Mean width.	Mean depth.	Mean of maximum depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
369	738	4,190	34.3	93.6	4,290	48.0	108.4
370	740	2,510	54.3	104.0	2,850	62.3	119.5
371	742	3,820	39.2	84.9	4,060	53.0	101.3
372	744	3,900	36.9	93.9	4,090	51.3	110.2
373	746	3,220	46.5	102.6	3,350	60.9	119.0
374	748	2,950	46.6	95.6	3,160	60.2	112.3
375	750	3,850	38.6	74.5	3,950	54.2	90.5
376	752	3,290	47.9	102.1	3,350	61.1	117.0
377	754	2,740	69.4	132.8	3,080	76.4	149.6
378	756	2,830	51.0	109.5	3,120	64.0	128.3
379	758	3,750	42.0	75.7	3,790	60.9	94.9
380	760	4,670	34.8	78.3	4,870	50.5	95.2
381	762	3,750	43.7	76.2	3,980	57.1	91.9
382	764	3,960	44.6	64.9	4,010	61.1	82.0
383	766	4,160	38.2	86.8	4,220	53.3	102.7
384	768	2,880	53.1	98.8	2,970	66.1	113.6
385	770	2,980	50.4	83.8	3,030	62.7	96.8
386	772	3,250	45.6	88.5	3,290	61.0	104.2
387	774	2,800	54.0	118.7	3,080	64.8	134.7
388	776	3,180	52.0	80.8	3,270	65.6	95.7
389	778	4,450	33.4	65.2	4,710	49.2	79.7
390	780	3,610	46.7	87.9	3,920	55.6	101.5
391	782	2,650	61.9	112.8	2,990	69.7	127.8
392	784	3,320	50.6	111.4	3,600	63.0	127.5
393	786	2,430	66.2	134.7	2,940	65.6	146.7
394	788	3,320	47.5	107.9	3,466	57.2	120.5
395	790	2,710	58.7	105.6	3,200	60.1	117.0
396	792	3,620	48.3	117.8	4,120	52.8	129.3
397	794	2,800	60.6	123.3	2,910	69.8	135.4
398	796	2,840	58.4	107.6	3,010	60.3	117.2
399	798	4,170	40.3	70.3	4,210	52.0	82.7
400	800	3,350	46.4	97.6	3,490	58.1	111.2
401	802	2,170	64.4	93.9	2,260	75.2	108.0
402	804	2,700	53.8	76.0	2,270	65.7	89.3
403	806	3,310	46.1	87.4	3,470	56.3	100.2
404	808	2,670	63.1	111.9	3,040	67.8	123.7
405	810	2,490	57.1	102.6	2,610	66.5	115.0
406	812	3,580	40.9	81.6	3,870	51.2	94.0
407	814	3,700	36.8	88.4	3,810	47.2	100.4
408	816	2,760	48 5	91.2	2,950	56.1	102.5
409	818	3,360	45.7	104.1	3,520	56.0	116.7
410	820	2,870	55.0	104.3	3,200	59.0	116.6
411	822	2,690	62.2	131.4	3,140	62.3	141.8
412	824	2,320	64.6	112.3	2,520	68.0	121.5
413	826	2,430	63.8	99.3	2,520	73.8	111.7
414	828	2,540	75.0	127.8	2,660	82.7	139.4
415	830	2,400	61.2	90.9	2,470	70.9	102.4
416	832	2,820	52.9	85.6	2,920	62.9	97.7
417	834	2,500	59.8	89.1	2,670	67.6	101.4
418	836	3,040	49.6	96.7	3,150	58.4	107.7
419	838	3,380	44.4	80.6	3,530	53.5	92.0
420	840	2,940	56.8	122.3	3,430	58.8	135.3
421	842	2,340	67.5	109.3	2,650	71.2	121.6
422	844	2,510	59.4	86.7	2,710	66.5	98.0
423	846	2,980	58.8	105.4	3,240	65.3	117.3
424	848	2,180	67.9	123.6	2,490	71.0	135.6
425	850	2,940	52.9	85.7	3,130	61.7	97.8
426	852	2,450	65.5	127.9	2,610	72.2	139.8
427	854	2,590	55.3	112.8	2,780	62.6	125.0
428	856	2,380	69.7	117.7	2,700	70.6	129.1
429	858	3,400	50.3	91.3	3,610	56.5	101.7
430	860	2,570	59.9	89.7	2,760	65.6	99.7
431	862	2,420	75.5	135.1	2,520	83.0	145.6
432	864	2,680	58.6	101.8	2,810	66.9	112.7
433	866	3,620	48.5	118.0	3,720	58.5	129.5
434	868	2,330	76.2	136.5	2,460	82.2	146.9
435	870	2,410	64.0	94.7	2,520	71.5	104.9
436	872	3,400	46.8	91.3	3,540	55.0	101.1
437	874	2,440	67.1	116.3	2,800	68.0	126.4
438	876	2,760	56.2	96.8	3,030	60.5	106.6
439	878	2,620	57.1	77.6	2,720	65.0	87.6
440	880	2,620	76.3	129.7	3,050	74.7	139.5
441	882	2,590	68.4	127.0	2,800	78.3	138.3

Mean widths, mean depths, and means of maximum depths of 2-mile sections of main river from Cairo, Illinois, to Head of Passes—Continued.

No. of section.	Distance from Cairo.	Medium stage.			Bank-full stage.		
		Mean width.	Mean depth.	Mean of maximum depth.	Mean width.	Mean depth.	Mean of maximum depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
442	884	2,460	73.9	122.3	2,580	80.8	132.7
443	886	3,010	58.6	97.3	3,380	61.2	107.3
444	888	2,600	74.3	126.0	3,030	73.1	137.8
445	890	2,330	87.2	149.8	2,400	94.9	158.8
446	892	2,120	73.2	113.0	2,170	80.2	121.1
447	894	2,130	72.6	129.2	2,180	80.4	137.2
448	896	2,110	80.2	147.0	2,190	85.2	155.0
449	898	2,080	76.9	131.7	2,170	82.0	139.7
450	900	2,350	65.8	96.4	2,440	72.0	104.4
451	902	2,430	63.1	96.9	2,480	69.8	104.4
452	904	2,430	75.5	125.1	2,480	81.2	132.1
453	906	2,720	59.2	95.6	2,780	65.3	102.6
454	908	2,360	69.2	109.6	2,410	74.7	116.6
455	910	2,161	77.1	111.6	2,199	83.0	118.2
456	912	2,407	73.1	96.7	2,447	78.4	103.8
457	914	2,399	68.3	99.9	2,434	72.8	105.9
458	916	2,443	71.5	111.3	2,462	76.5	117.3
459	918	2,343	80.6	114.6	2,360	85.3	120.4
460	920	2,241	71.9	111.6	2,261	76.3	115.4
461	922	2,140	74.4	108.4	2,163	78.1	113.4
462	924	2,056	72.6	112.1	2,093	75.0	117.1
463	926	2,971	63.2	99.1	3,001	66.6	104.1
464	928	3,170	54.8	98.6	3,354	56.3	102.6
465	930	2,376	69.8	116.7	2,438	71.3	120.8
466	932	2,184	60.1	98.7	2,224	62.0	102.7
467	934	2,412	59.4	95.2	2,456	61.1	99.2
468	936	2,840	79.1	136.6	2,921	80.2	140.4
469	938	2,399	67.3	106.7	2,424	69.5	109.7
470	940	2,255	69.9	97.3	2,275	71.9	100.3
471	942	2,147	74.1	100.9	2,164	76.2	112.9
472	944	2,663	60.3	99.8	2,675	63.1	102.8
473	946	2,651	62.7	104.2	2,669	64.9	108.9
474	948	2,191	64.6	115.9	2,217	66.1	117.9
475	950	2,124	74.6	118.9	2,149	78.1	120.9
476	952	2,630	66.8	104.3	2,650	68.1	106.3
477	954	2,878	61.1	94.4	2,886	62.5	96.4
478	956	2,397	76.8	132.0	2,404	78.0	133.7
479	958	.....	.....	.....	2,391	81.1	125.4
480	960	.....	.....	.....	2,666	65.5	101.3
481	962	.....	.....	.....	2,072	77.9	109.2
482	964	.....	.....	.....	2,039	90.2	124.6
483	966	.....	.....	.....	2,152	98.4	147.7
484	968	.....	.....	.....	2,438	71.9	91.9
485	970	.....	.....	.....	2,420	67.0	94.4
486	972	.....	.....	.....	2,543	63.0	103.7
487	974	.....	.....	.....	2,376	68.4	108.1
488	976	.....	.....	.....	2,484	65.9	95.4
489	978	.....	.....	.....	2,423	72.5	113.6
490	980	.....	.....	.....	2,313	74.0	109.8
491	982	.....	.....	.....	2,231	80.5	118.1
492	984	.....	.....	.....	2,268	64.4	93.3
493	986	.....	.....	.....	2,200	65.8	102.9
494	988	.....	.....	.....	2,426	60.5	93.5
495	990	.....	.....	.....	2,417	58.8	93.3
496	992	.....	.....	.....	2,278	64.0	98.7
497	994	.....	.....	.....	2,429	61.2	94.4
498	996	.....	.....	.....	2,163	73.1	104.0
499	998	.....	.....	.....	2,204	75.6	125.0
500	1,000	.....	.....	.....	2,427	75.3	124.3
501	1,002	.....	.....	.....	2,492	60.0	82.7
502	1,004	.....	.....	.....	2,292	62.9	100.3
503	1,006	.....	.....	.....	2,462	57.7	100.2
504	1,008	.....	.....	.....	2,586	56.3	105.1
505	1,010	.....	.....	.....	2,461	62.8	99.4
506	1,012	.....	.....	.....	2,837	55.2	101.7
507	1,014	.....	.....	.....	2,237	85.2	140.1
508	1,016	.....	.....	.....	2,717	56.8	100.4
509	1,018	.....	.....	.....	2,380	61.3	91.6
510	1,020	.....	.....	.....	2,342	64.3	107.4
511	1,022	.....	.....	.....	2,218	67.2	115.8
512	1,024	.....	.....	.....	2,270	73.5	114.0
513	1,026	.....	.....	.....	2,426	66.5	113.8
514	1,028	.....	.....	.....	2,174	67.0	110.6

Mean widths, mean depths, and means of maximum depths of 2-mile sections of main river from Cairo, Illinois, to Head of Passes—Continued.

No. of section.	Distance from Cairo.	Medium stage.			Bank-full stage.		
		Mean width.	Mean depth.	Mean of maximum depth.	Mean width.	Mean depth.	Mean of maximum depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
515	1,030				2,490	60.9	102.1
516	1,032				2,581	60.5	102.1
517	1,034				2,744	63.9	115.1
518	1,036				2,349	76.4	115.8
519	1,038				2,187	94.7	157.2
520	1,040				2,637	70.6	113.7
521	1,042				2,537	61.0	90.2
522	1,044				2,526	61.8	82.6
523	1,046				2,638	61.7	83.5
524	1,048				2,771	58.9	100.6
525	1,050				2,634	57.0	94.3
526	1,052				3,252	52.6	85.8
527	1,054				3,967	41.3	63.6
528	1,056				4,852	38.9	48.5
529	1,058				7,177	27.0	38.3

REPORT OF CAPTAIN CHARLES F. POWELL, CORPS OF ENGINEERS, UPON RELATION BETWEEN MEAN BANK HEIGHT AND MEAN HIGH WATER.

ST. LOUIS, MO., *January* 10, 1890.

GENERAL: I have to submit the following report of the results of an investigation of the relation between mean heights of the Mississippi River banks at or near certain stations below Cairo, and mean high water as found from the yearly high-water readings since 1872 inclusive, as requested in your letter of September 25.

Ten gauge stations, Cairo, Memphis, Helena, mouth of White River, Lake Providence, Vicksburg, Natchez, Red River Landing, Baton Rouge, and Carrollton, were available. Carrollton was not used at first, since the bank elevations at that place were not then known. One year's high-water readings at Red River Landing are missing; interpolating from the adjacent stations, Natchez or Baton Rouge, the eighteen-year mean at the landing is 41.9 feet. This was used. The seventeen-year mean is 42.1 feet. Three years' high-water readings are missing at mouth of White River; one year was supplied by an observed high-water mark; the mean, 45.3 feet, of the sixteen years was used. The eighteen-year mean with interpolated values from Helena the two missing years is 44.7 feet, and from Lake Providence, 45.3 feet. There is a closer correspondence or relation between the Helena and White River high-water readings than between those of White River and Lake Providence, and, considering distances between gauges and probable influence of tributaries, I think now that it would have been safer to interpolate for White River from Helena. Such method would reduce the local difference of elevation between mean bank and mean high water from that given in the table below.

To increase the number of observations and to divide the distances between the stations named, I thought it desirable to also include in the investigation those gauge stations, established in 1880, where the mean high water since 1872 could be deduced within a fairly close approximation to the actual value. For determining this the differences between corresponding observed yearly high waters at each of the 1880 stations and the adjacent 1872 stations were noted, and the rule adopted to select those 1880 stations where the range of differences was less than 2.5 feet, a small range being evidence of a close relation between the corresponding high waters at the respective stations. The stations thus selected and the ranges of differences are, Fulton, 2.46 feet; Arkansas City, 1.3 feet; Greenville, 1.57 feet; St. Joseph, 2.26 feet, and Port Hickey, 1.20 feet. The adopted mean for each 1880 station was then derived from the proportion comprised by the means of the corresponding high waters at the station and at its standard 1872 station, and the eighteen-year means for the same stations.

With the mean high-water readings thus adopted, the bank elevations from the topographic surveys, and observed local high-water slopes, assistant engineer C. W. Clark has obtained the differences between mean high-water and mean bank for two or more reaches, generally 3 miles long, at or in the immediate vicinity of the sta-

tions. He has also noted and discussed for each station the physical conditions which in our judgment might influence the river's effort to build its banks. Mr. Clark's report with tabulation is attached.

Subsequently some bank sections at and near Carrollton were obtained, from which it is found that the right bank is 0.2 foot higher and the left bank 0.9 foot lower than mean high water. The bank elevations here are not sufficient in number nor distribution to give a comparison with mean high water as satisfactory as at the other stations. A deterioration of the immediate bank from wear and steamer wash might be expected at a large harbor and in a greater degree on the occupied side.

To divide the otherwise long distance from Baton Rouge to Carrollton for our comparison of mean high water with mean bank, and to try another method of obtaining the comparison, a plot was made of the bank elevations from Baton Rouge to Donaldsonville (the limit towards Carrollton of the topographic survey) and of a mean high-water grade line over the same reach. This line was obtained by adjusting from observed high-water slopes at intermediate stations the average grade, plotted by connecting the mean high-water readings at Baton Rouge and Carrollton, the including stations. The adjustment having been carefully made and for a part at an end of the reach, and of less than one-half the distance of the whole, any resulting error of the mean high-water grade is thought to be quite inconsiderable. From this plot it is found that the right bank, Baton Rouge to Donaldsonville, has 36 miles above and 16 miles below mean high water, averaging 0.53 foot above; and the left bank 36.5 miles above and 15.5 miles below, averaging 0.50 foot above mean high water.

Summarizing the measurements, it may be stated that at the stations and on the reach examined the bank from Cairo to Memphis, 230 miles, is from 0.5 foot to 2.8 feet above mean high water; from Memphis to Chotard Landing, 240 miles, the bank is below from 0.4 foot to 1.4 feet; from Chotard Landing to Donaldsonville, 314 miles, the bank is above from 0.2 foot to 3.8 feet, and at Carrollton is below, about 0.4 foot. Also that, on the whole, the mean bank, Cairo to Carrollton, is somewhat above adopted mean high water.

The adopted means have been obtained from the systematic and continuous gauge readings; they may not be the true ones, although eighteen years' reliable observations ought to give good results. If the means differ from true ones, they would most probably do so by respective corrections about proportional to the ranges, exhibited in the table below, between the adopted mean high and highest water on the gauges:

Station or reach.	Interval or length.	Mean bank as to mean high water.	Length of reach.	Well defined cut-offs.	Doubtful cut-offs.
	Miles.	*Feet.*	*Miles.*		
Cairo		0.5 above			
Fulton	175	2.8 above			
Memphis	55		230	2	9
Helena	76	1.4 below			
White River	87	0.9 below			
Arkansas City	40	1.1 below			
Greenville	45	0.4 below			
Lake Providence	74	0.5 below			
Chotard Landing	28		240	17	17
Vicksburg	29	0.6 above			
St. Joseph	48	0.8 above			
Natchez	52	3.8 above			
Red River Landing	65	1.4 above			
Port Hickey	45	2.6 above			
Baton Rouge	23	0.2 above			
Baton Rouge to Donaldsonville	52	0.5 above	314	13	2
Carrollton	72	0.4 below	72		

Station or reach.	On gauge, 1872–1889.					
	Mean high water.	Lowest water.*	Highest water.	Range.		Average yearly duration high above mean high.
				Highest and lowest.	Highest and mean high.	
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Days.*
Cairo	44.34	—1.00	52.17	53.17	7.83	14
Fulton	33.04	+1.69	38.69	35.00	3.65	.....
Memphis	32.52	—0.95	35.30	36.25	2.78	21
Helena	42.81	—0.20	48.10	48.30	5.29	18
White River	†45.33	.....	48.40	48.40	3.07	17
Arkansas City	44.09	+0.30	47.00	46.70	2.91	.....
Greenville	39.48	+1.85	41.68	39.83	2.20	.....
Lake Providence	36.55	—3.85	38.40	42.25	1.85	24
Chotard Landing	.....	.....	.....	.....	.....	.....
Vicksburg	42.90	—3.92	49.00	52.92	6.10	25
St. Joseph	39.77	.....	44.90	.....	5.13	.....
Natches	42.20	.....	47.75	47.75	5.55	29
Red River Landing	41.92	.....	48.50	48.50	6.58	25
Port Hickey	42.19	.....	47.90	.....	5.71	.....
Baton Rouge	31.73	+1.15	36.20	35.05	4.47	26
Baton Rouge to Donaldsonville	.....	.....	.....	.....	.....	.....
Carrollton	13.28	—1.60	15.70	17.30	2.42	26

* From 1880–1889 only, for Fulton, Arkansas City, and Greenville.
† Interpolating for two missing years from Helena the eighteen-year mean would be 44.7.

It may be noticed from Mr. Clark's discussion that the more pronounced physical characteristic of the river or its banks, subject to control and therein discussed, and which presents a concurrence with bank height, is a degree of permanence of bank; it is justly concluded from the observations that convex banks are generally high; that the indications are that concave banks are low; that a caving bank does not build high, while freedom from caving insures high bank, and that for stable convex or straight bank, mean bank is almost always higher than mean high water. The concurrences might be expected as logically resulting from the well known processes of bank-building by river deposits.

The conclusion of a relation or dependence between bank stability and high bank is verified from a consideration, exhibited in the table above, of bank elevations in reference to reaches of cut-offs, and in view of the fact established by numerous observations that cut-offs induce bank-caving above and below. To serve as an extension of the table on this point, it might be explained that below Carrollton no evidences of cut-offs are shown on our maps, and a reference made to the statement in the report of the committee on levees, appendix F of the Commission's report, 1881, that below the forts the banks are approximately at the level of flood plane, and also the fact that the lower part of the river has generally stable and straight banks.

The conclusion seems warranted that banks somewhat higher than otherwise will result, incidentally, from bank protection and prevention of cut-offs, two objects to be attained in the Commission plans for river-channel improvement.

The observations further appear to show where the direction of overflow is normal to the river that the banks are less high than where the overflow is oblique, nearly parallel, or parallel to the river, the latter class not including the case of points over which water escapes and falls into the river on their lower sides. Other things being equal, especially in the matter of obstructions to the flow, these results may be explained by the greater slope of the ground away from the river than along it, sometimes as much as twenty times greater; and by the fact that when the velocity of overflow is slackened by the filling of reservoirs the induced deposits occur at or near the bank for parallel and oblique overflows, and more remote from the bank for normal overflows.

The tabluated observations do not show that the natural bank height is influenced by levees; it should be noticed, however, that in these observations the banks examined as to levees are above Baton Rouge, and are where the levees had been very generally disconnected and were back from the immediate bank of the river; also that the number of observations as to levees is not large.

Below Baton Rouge the levees have been generally continuous, were much older, and are close to the river. A detailed examination was made as to the levees on the

right bank from Port Hickey, and on the left bank from Baton Rouge, to Donaldsonville, and it was found that the natural ground outside (river side) of the levees averaged about 2.1 feet above the ground inside (land side of the levees, at a few places the outside ground being within a foot of the levee top. About 0.7 feet of the difference is accounted for by the natural slope of the ground back from the river as found from 107 half-mile bank sections below Hermitage Landing, and a consideration of the average distance of the observed elevations on the two sides of the levee. Some exaggeration of the difference may further have come from outside elevations having been taken on unidentified old levee and possibly from inside elevations at borrow-pits. After liberally allowing for these conditions the available data show that on the lower part of the river the levees have not stopped the bank building process. To find whether they have aided or retarded it a test was made as to permanence of levee from a comparison of locations by the Delta survey and the present survey on the common part and where the connections were not doubtful, viz: on the right bank from Fausse River, and on the left bank from Baton Rouge, to Donaldsonville. Twenty-three reaches are available for comparison. Dividing them into three classes, (1) Where the levees of 1851 were intact or nearly intact in 1883, aggregating 58 miles; (2) Where parts of the levees of 1851 remained but with considerable change of the other portions, 30 miles; and (3) Where the levees of 1851 had entirely or almost entirely disappeared, aggregating 33 miles, it was found that the difference of average heights of ground outside and inside of levees were respectively 1.4, 2.0, and 2.3 feet. The available reaches were further divided into classes, according to the plan of the levee and to its location, as in bend or on straight bank, etc., from which the following was obtained:

Average difference of elevations outside and inside of levee.	Conditions.
2.2 feet	Levee line very angular; many spurs towards the shore.
1.9 feet	Levee line less broken; fewer spurs than above.
1.3 feet	Levee smooth; very few spurs on sharp turns.
2.1 feet	Levee in bends.
1.9 feet	Levee along straight banks.
1.5 feet	Levee on points included by straight reaches.
0.8 feet	Levee line points.

It thus appears that either permanent levees on the lower part of the river, where close to the shore, retard the bank building, or, what seems more decided, that the broken line of levee with outward spurs or wings favors the process.

The effect on bank building of wooded as against cultivated ground is discussed by Mr. Clark, and also that of certain characteristics of the river not subject to control or change; of the latter class the effect of tributaries appears to be the most pronounced.

Very respectfully, your obedient servant,

CHAS. F. POWELL,
Captain, Corps of Engineers.

Gen. C. B. COMSTOCK, U. S. A.,
President Mississippi River Commission.

REPORT OF MR. C. W. CLARK, ASSISTANT ENGINEER.

OCTOBER 26, 1889.

CAPTAIN: I have the honor to make the following report upon relative heights of mean bank and mean high water of the Mississippi River, Cairo, Ill., to Baton Rouge, La. Fourteen stations were used for the comparison.

* * * * * * *

The number of reaches examined vary from two to five at each station; a total number of forty-one reaches was used.

In some cases the reach considered lay entirely above or below the gauge; in such cases a slope correction for the distance from the center of the reach to the gauge was applied, the slope per mile being determined from the high-water slopes for several years, as published in the Mississippi River Commission Reports for the respective stations considered. * * * The majority of the reaches considered were 3 miles each in length. Where levees or railroad embankments lay near the shore, elevations

each side of the same were used in getting the mean. At Cairo and Memphis published charts were used (principally) for getting the bank heights; for the other twelve stations the original field plats were used. The average number of elevations used for getting bank height for a single reach was about eighteen or twenty, but in extreme cases seven to thirty were used. It is believed that the mean bank was in each case quite accurately determined in this way.

Tabulated sheets numbered 1 to 11 give the "Mean high waters," "Extreme high waters," "Mean bank elevation," "Differences," by subtracting mean bank from mean high-water elevations, and descriptions of reaches, their location, etc., so that only a discussion of the results need be taken up here. In the following M. B. will be used for mean bank, M. H. W. for mean high water, and E. H. W. for extreme high water.

Of the forty-one reaches we find that twenty-one have M. B. higher than M. H. W., eighteen have M. B. lower than M. H. W., and two have M. B. same as M. H. W. Out of the fourteen stations eleven have one or more reaches where M. B. is greater than M. H. W., and nine have one or more reaches where M. B. is less than M. H. W. Taking the mean of the M. B.'s at each station, we find that at eight stations M. B. is higher than M. H. W., and at six stations M. B. is lower than M. H. W. The latter six are in regular order taken from Memphis to Lake Providence, viz, Memphis, Helena, Mouth of White River, Arkansas City, Greenville, and Lake Providence.

The following conditions regarding the reaches will be considered to determine, if possible, their effect on bank building: (1) Bank leveed or unleveed; (2) bank cultivated or wooded; (3) bank convex, concave, or straight; (4) bank caving rapidly, slightly, or not at all; (5) flood water flowing over bank out of river, over bank into river, or over bank parallel, or nearly parallel, to shore; (6) Entrance of tributary into the river; (7) bluffs near bank; (8) range of H. W. elevations for the series of years considered at each station, and (9) Length of time that water remains above mean high water.

1. Where levees lie near the shore we find at seven reaches (representing five stations) M. B. is higher than M. H. W., nine reaches (representing six stations) M. B. is lower than M. H. W., and two reaches (representing two stations) M. B. is the same as M. H. W. On reaches where there are no levees back we find at nine reaches (representing five stations) M. B. is higher than M. H. W., and eight reaches (representing five stations) M. B. is lower than M. H. W. Of cases where levee lies back of a part of the reach we find five reaches (representing five stations) where M. B. is higher than M. H. W., and one reach M. B. is lower than M. H. W. It would seem from the above that the fact of the bank being leveed or not has little effect on the bank building at the reaches considered, elevations each side of the levee being taken to get the mean. It is true that the ground outside (river side) the levee is usually a little higher than inside (land side), about 0.45 feet, as shown by an examination of about 500 miles of river above Baton Rouge—levee averaging about one-fourth of a mile back—(see Mississippi River Commission Reports 1882 and 1883); but the high ground is usually less than one-fourth of a mile back, and the natural slope (for probably one-eighth of a mile) of the ground back from high ground would have to be considered. Now as bank slopes from 4 to 10 feet per mile away from the river (Mississippi River Commission Report 1882) we should expect to find a difference of that amount or more due to slope alone. From the last consideration it would seem more nearly correct to take only elevations outside the levee where it lies more than about one-eighth of a mile back. In the cases actually considered, however, the introduction of the elevations back of the levee in no case had an effect of changing the mean more than 0.1 foot or 0.2 foot, and in most cases probably the mean was not affected by an appreciable amount.

2. Of reaches where the banks were cultivated, we find eight reaches (representing six stations) where M. B. is higher than M. H. W., and seven reaches (representing four stations) where M. B. is lower than M. H. W. Where banks are wooded we have four reaches where M. B. is higher than M. H. W., and two reaches M. B. lower than M. H. W. Where banks are partly cultivated and partly wooded we have nine reaches where M. B. is higher and nine reaches where it is lower than M. H. W. As far as these results go there is but little to indicate that there is any difference in the bank-building process between cultivated and wooded banks; but as in general the higher lands have originally been selected for cultivation it is perhaps not a correct test to make a comparison in this way. It seems reasonable to expect that wooded banks by arresting the flow of water would cause a greater deposit, but it is possible that this might be offset by the greater volume of water that would flow over the unobstructed (cultivated) bank.

3. Where bank is convex we find ten reaches (representing seven stations) where M. B. is higher than M. H. W., and four reaches (representing four stations) where M. B. is lower than M. H. W. Where bank is concave we have three reaches (three stations) where M. B. is higher than M. H. W., and five reaches (five stations) where M. B. is lower than M. H. W., and one reach where M. B. is same as M. H. W. Where

bank is partly convex and partly concave we have one reach M. B. is higher and two reaches lower than M. H. W. Where banks are straight we have seven reaches (representing four stations) where M. B. is higher than M. H. W., seven reaches (representing four stations) M. B. is lower than M. H. W., and one reach M. B. is same height as M. H. W. We notice from the above that convex banks are generally high, while the indications are that concave banks are low, although the data here is hardly sufficient by itself to make this conclusive; we would expect, however, that the caving banks would be low, and they are generally the concave banks; where banks are straight, we see there is an equal division between the high and low banks.

4. Where banks were caving rapidly (at time the survey was made) we have two reaches where M. B. was higher, two reaches lower, and one reach same as M. H. W. Where bank was caving, but not rapidly, we have seven reaches (representing five stations) M. B. higher, and twelve reaches (representing eight stations) lower than M. H. W., and one reach M. B. same height as M. H. W. Where banks were not caving (at time of surveys), we find twelve reaches (representing ten stations) where M. B. is higher than M. H. W., and four reaches (four stations) where M. B. is lower than M. H. W. Although the caving at time of survey is not a sure indication of what the bank has been doing the period of eighteen years under discussion, yet these observations would go to show that the bank does not build up to its normal height while subject to caving, while freedom from caving insures high bank building, other conditions being normal.

If we examine this condition (4) in connection with the previous one (3) we find that for the convex bank where M. B. is higher than M. H. W., seven out of the ten cases are where bank is not caving, two where it is caving slightly, and one where it is caving rapidly; where M. B. is lower than M. H. W. we find one case bank not caving, the other three cases bank caving. For concave banks where M. B. is higher than M. H. W., one case not caving, two cases caving slightly; where M. B. is lower or same height as M. H. W., two cases not caving, four cases caving, (three cases caving rapidly). For straight bank where M. B. is higher than M. H. W., four cases not caving, three cases caving; where M. B. is lower than M. H. W., only one case is where bank is not caving and seven cases where it is caving. The above shows that where bank is convex or straight and not caving M. B. is almost always higher than M. H. W.; only two cases out of thirteen to the contrary.

5. In most cases there is no data except position of contours to determine the direction of flow of flood waters over the banks and it is doubtless the case that for a number of the reaches here considered the water flows over the banks to low grounds but is put down here as flowing parallel to the shore; because the direction of flow is at such an acute angle with the shore that the contours are not a precise enough guide for determining the actual conditions; the effect on bank building would be but little different, probably, as it is pretty safe to assume that water flowing from the basins into the river will seldom, if ever, come under the above conditions of flow; so that we may assume that waters flowing along the bank and nearly parallel with it have but recently left the river. We find from the tabulations that where water flows back to low ground over the banks, at three reaches (representing three stations) the M. B. is higher than M. H. W. and eight reaches (representing five stations) M. B. is lower than M. H. W. Where water is flowing over the banks into the river we find one reach M. B. is higher and two reaches lower than M. H. W. Where the water flows over the banks and apparently parallel to them we find seventeen reaches (representing nine stations) where M. B. is higher than M. H. W., eight reaches (representing seven stations) where M. B. is lower than M. H. W. and two reaches where M. B. is the same as M. H. W. These results show that flood waters flowing over bank and nearly parallel with it are the best conditions for high bank building.

6. In cases of tributaries emptying into the river we find that the bank below on the tributary side is lower than the bank on the opposite side of the river. At Cairo (considering the Ohio River a tributary) it is 1 foot lower; at Helena it is 3.3 feet lower; at mouth of White River it is 0.5 foot lower, and at Red River Landing it is 3.5 feet lower. The banks below mouths of Arkansas and Yazoo rivers were also examined and the same condition found to exist; at Arkansas River the bank on tributary side is 0.5 foot lower than the opposite, and at Yazoo River it is 1.5 feet lower. It seems probable that the cause for this is that the water of the tributaries is less heavily laden with silt, etc., and, to a certain extent, dilutes the water flowing along the bank below the mouth from which it empties, and perhaps in some cases materially deflecting the heavily laden waters of the main river to the opposite bank.

7. Where bluffs are on the same side and in the vicinity of the reach we find seven reaches (representing seven stations) where M. B. is higher than M. H. W., and four reaches (representing three stations) where M. B. is lower than M. H. W. Of the first seven cases six were where the reach lay below or mostly below where bluffs make back from near the shore, and in the remaining case a point of bluffs

comes near shore about the center of the reach. Of the four reaches where M. B. is lower than M. H. W., only one lies below where bluffs make back from the river, and in that case the reach is 1.8 feet higher than one directly above lying in front of the bluffs; one reach in this class lies entirely above the bluffs, the remaining two lie in front of the bluffs. Thus we see that where a line of bluffs makes back from the river it aids in bank building on reaches immediately below and on the same side of the river. This is probably due to the flood water being confined by the bluffs above, on that side, and spreading out over the flats below the bluffs with decreased velocity.

8. Taking the differences between M. H. W. and extreme H. W. for the period of eighteen years at the fourteen stations, we find the mean to be 4.5 feet. Now, where the average M. B. is higher than M. H. W., we have six cases where the above-mentioned difference at a station is greater than this mean difference, and only two such cases where it is less; on the other hand, where the average M. B. is lower than M. H. W. we find five cases where this difference is less than this mean difference, and but one case where it is greater. This shows that a great range in the elevations of high waters at a station is favorable to high-bank building. If we consider the differences between M. H. W. for this period of eighteen years and extreme H. W.'s known at the several stations, the only effect on the above is to somewhat increase the mean difference, but not sufficiently to change any of the above conditions.

9. *Length of time that water remains above M. H. W.*—For this investigation a period of eighteen years was taken, and the mean number of days per year found, during which the flood waters remained above M. H. W. at each of the fourteen stations; where observations at a station did not extend over the entire period, a comparison was made for the observed years with the corresponding years for contiguous stations having the observations complete, and thus a proportion formed for determining the mean for the period of eighteen years; the results thus found are probably very close to the true result. In most cases a comparison was made with contiguous stations above and below, and the greatest difference thus found in the two results was three days, other cases differing but one day. The average period for stations where M. B. is higher than M. H. W. is twenty-four and a half days, and where M. B. is lower than M. H. W. the average is twenty-one and a half days. Taking a mean of this period for all the stations, we find that where M. B. is higher than M. H. W., at two stations the number of days above M. H. W. is less than this mean, and at six stations it is greater; where M. B. is lower than M. H. W., at two stations it is above this mean and at four stations below. For the stations with extreme high and low banks we find for the period above M. H. W. at Natchez (the highest bank) twenty-nine days; at Fulton (next highest bank) eighteen days; Port Hickey (next to Fulton in high banks), thirty-four days; Red River Landing (next to Port Hickey), twenty-six days; at Helena (lowest bank), eighteen days; Arkansas City (next lowest bank), eighteen days, and mouth of White River (next to Arkansas City in low banks), twenty days. From the above we conclude that in general a long period for flood waters above M. H. W. is favorable to high-bank building.

An examination was also made of the average number of days per year in which the flood waters remained above the mean bank at each of the stations. The average period for stations where M. B. is higher than M. H. W. is fourteen and one-half days, and where M. B. is lower than M. H. W., twenty-nine days.

For stations with high banks we have in their order Natchez three days, Fulton two and one-half days, Port Hickey seventeen days, and Red River Landing eighteen days; for stations with low banks we have in order Helena thirty-two days, Arkansas City twenty-nine days, and Mouth of White River twenty-nine days. Thus we see that the present conditions are that stations with low banks are submerged much longer than those stations with high banks, although the period for flood waters above M. H. W. is generally less for the stations with low banks. We see that the condition of long period of flood is to-day favorable to stations of low banks, in comparison with those of high, while at some period in the past the reverse has been true.

Of the nine conditions considered we have found that for one and two, the effect on bank building is indifferent; for three and four in connection, a convex or straight bank not caving is favorable to high-bank building, while convex and caving the effect is indifferent; while for straight or concave banks caving, the tendency is against high banks especially if the caving is rapid; for five flood waters flowing over bank normal to it are detrimental to high-bank building, while flowing over and nearly parallel with the bank is beneficial to high-bank building; for six, we found the entrance of tributaries detrimental to bank below on tributary side while possibly beneficial to the opposite bank; for seven, we found bluffs making back from bank was beneficial to high-bank building below and on the same side of the river; for eighth case we found a wide range in elevations of high waters beneficial to high-bank building; and for ninth case a long period of flood waters above M. H. W. is favorable to high bank building. It is not possible with the data at hand to give with certainty a correct ratio to these different individual conditions in examining their combined

effect. We will assume weights, however, as follows: First, for favorable conditions, convex or straight bank, not caving (1); flood water flowing over and parallel to bank (½); bluffs making back from bank above reach (1); range of elevations above the mean range (1); where the number of days that the water is above M. H. W. at a station exceeds the mean for all stations by from two to five days, (½); where from five to ten days, (1); and where over ten days, (1½); second, for unfavorable conditions; concave or straight bank caving rapidly, (1); concave or straight bank caving (but not rapidly), (½); water flowing over and normal to bank, (½); entrance of tributary above, (½); range of elevations of high water below the mean range, (1); where the number of days that the water is above M. H. W. at a station is less than the mean for all stations by from two to five days, (½); where from five to ten days, (1); and where over ten days, (1½). Applying these weights to the conditions for each individual reach and summating them for each station we get the following table:

Station.	Sum of weights of conditions.		Average M. B. above or below M. H. W.
	Favorable.	Unfavorable.	
Cairo	5½	3½	Above 0.52 foot.
Fulton	3	2	Above 2.80 feet.
Memphis	2	4	Below 0.65 foot.
Helena	3	4½	Below 1.40 feet.
Mouth of White River	½	6	Below 0.92 foot.
Arkansas City	1½	3	Below 1.10 feet.
Greenville	1½	2½	Below 0.35 foot.
Lake Providence	1	1	Below 0.55 foot.
Vicksburg	6	1½	Above 0.62 foot.
St. Joseph	3	.....	Above 0.75 foot.
Natchez	5	½	Above 3.77 feet.
Red River Landing	2½	1½	Above 1.35 feet.
Port Hickey	6	.....	Above 2.60 feet.
Baton Rouge	2½	1½	Above 0.25 foot.

This table shows that in all cases where M. B. is greater than M. H. W. the percentage of favorable conditions is greater than that of unfavorable, and where M. B. is lower than M. H. W. the reverse is true, with the single exception of Lake Providence, where the percentages of favorable and unfavorable conditions are the same.

At Helena we find the extreme low bank, being 1.4 feet, lower than M. H. W.; this may be largely accounted for by the large volume of water flowing from the St. Francis Basin into the river at this station. This flood water having traveled for many miles, mostly among timbered lands, has probably lost a large percentage of the sediment taken from the river and gathered a small amount from the basin, so it is probably carrying a comparatively small percentage when it passes Helena.

At Natchez we find the maximum height of bank being 3.77 feet above M. H. W., and here we find the conditions almost entirely favorable to high-bank building.

At Vicksburg we find the conditions very favorable were it not for the flood waters from the Yazoo Basin; except for this condition we might expect to find Vicksburg with a maximum or nearly maximum height of bank.

It is quite possible that there are other conditions having good or bad effects on bank building which have not been noticed in this paper, but it is believed the principal ones have been examined, and it seems, when taken in combination, that they explain fairly well the conditions of banks that we find for the several stations.

The results finally show that the banks may build considerably above mean high water where a large percentage of the above-found favorable conditions exist, but that at many places there are enough unfavorable conditions to prevent the bank from building to a height equal to M. H. W., so it would seem that the mean bank for the river through the alluvial valley is not far from the height of M. H. W., with a probability of its being a little higher.

Very respectfully, your obedient servant,

C. W. CLARK,
Assistant Engineer.

Capt. CHAS. F. POWELL,
Corps of Engineers,
Secretary Mississippi River Commission.

Locality.	Mean elevation of banks above Memphis datum.	Difference—mean bank and mean high-water elevations.	Remarks.
Cairo:	*Feet.*	*Feet.*	
Mean high water above Memphis datum 1872–1889, inclusive, 322 feet.	*322.1	—0.1	Kentucky shore: Mean for 3-mile stretch on Kentucky shore-elevations from Comstock charts, shore slightly convex, not caving, about one-half wooded, the rest cultivated. No levee or railroad at this date, but railroad begins near the lower end of this reach and lies near shore.
Extreme high water above Memphis datum, 339.9 feet.	323.1	—1.1	Missouri shore: From center of Bird's Point to a point 3½ miles above; shore caving 50 to 75 feet per year, partly concave and partly convex; about three-fifths of the reach wooded, the rest cultivated; old levee and railroad average three-sixteenths mile back of bank on one-half of the reach; no levee, etc., back of rest of the reach; the lower end of Illinois lies between the gauge and this reach; on lower three-fourths mile of this reach H. W. flows back almost normal to bank across the point.
	†322.8	—0.8	Missouri shore: 3-mile reach, the center of which is 4½ miles below the gauge; bank straight, no caving; two-fifths cultivated, the rest wood; back of the upper three-fourths of this reach is an old bank higher than the present one; is about 323 feet high. At upper three-fourths mile of this reach, high water flows from across the point into the river.
	†322.5	—0.5	Kentucky shore: 3-mile reach, the center of which is 4½ miles below the gauge; shore straight; all woods; but little caving; bluffs one-fourth mile back of upper half of reach.
	*322.1	—0.1	Missouri shore: 3-mile reach, whose center is about 4½ miles above the gauge; straight shore; slight caving; mostly woods.
Memphis:			
Mean high water above Memphis datum 1872–1889, inclusive, 222.4 feet.	222.5	0.9	Left bank: 1½-mile reach, lower end about one-fourth mile above gauge; bank concave, caving rapidly on part of the reach; one-half of reach cultivated, the rest woods; contours indicate that H. W. flows across point and islands above and into the river along this reach; bluffs at and below the gauge prevent taking elevations from that part.
Extreme high water above Memphis datum, 226.1 feet.	‡223.3	0.1	Right bank: 3-mile reach opposite the gauge; bank convex, slightly caving; about three-fourths of reach woods, rest cultivated; levee average one-eighth mile back; elevations on both sides of levee used, but slight if any difference of elevations on the two sides of levee; sand-bar in front of the greater part of the reach.
	§223.5	—0.1	Left bank: 4-mile reach, the center of which is 7½ miles above Memphis gauge; bank concave, slightly caving; about two-fifths cultivated, the rest wooded, brush, vines, etc.; Ash Slough and Hatchee Lake average one-fourth mile back of the lower two-thirds of this reach; H. W. flows across to Hatchee Lake in places; a point of bluffs comes to within one-eighth mile of bank near center of this reach, but extends only a short distance near the shore.
	§224.1	—0.7	Right bank: 4-mile reach, the center of which is 7½ miles above gauge; bank convex, mostly wooded, slight if any caving; old levee average three-eighths mile back of about one-half of the reach; sand-bar in front of most of the reach.

* This result is from the reach most favorably located with reference to the gauge and may be considered more reliable than the other results.

† A slope correction applied to get these results; no H. W. slope, directly at Cairo, is known, but the mean for 1880, 1882–1884, inclusive, from Cairo to Columbus and points above Columbus, was used, this may cause a possible error in these results of 0.3 foot or 0.4 foot, but I judge the error is not more than 0.1 foot or 0.2 foot from this cause. Elevations for last result were taken from field plats of Mississippi River Commission surveys; for the other results, taken from Comstock charts.

‡ This result from reach most favorably located with reference to the gauge.

§ A slope correction applied to get these results was found by taking mean of H. W. slopes for 1880, 1882 to 1884, inclusive, and 1886–1888, inclusive.

Locality.	Mean elevation of banks above Memphis datum.	Differences—mean bank and mean high-water elevations.	Remarks.
Helena:	*Feet.*	*Feet.*	
Mean high water above Memphis datum 1872–1889, inclusive, 191.7 feet.	188.5	3.2	Right bank: 3-mile reach, gauge at center of reach; bank nearly straight, cultivated, some caving at lower part of reach; old levee and railroad near the bank for three-quarters distance over reach, from lower end tow-head in front of the reach; elevations back of levee and railroad not used because of grading of streets and of filling caused by material washed down from bluffs; lake and low ground next bluffs above Helena; water from St. Francis Basin comes to river just above Helena in flood season; mouth of St. Francis River 8¾ miles above gauge.
Extreme high water above Memphis datum, 197.0 feet.	191.8	—0.1	Left bank: 3-mile reach opposite the gauge; bank nearly straight, not caving; about one-half of reach cultivated, the rest wooded; old levee will average about seven-eighths mile back of the bank; lakes and low ground between the bank and the levee; a railroad runs directly back from the bank near the center of the reach considered; water flows over this bank and into Yazoo Basin during floods.
	*190.3	1.4	Right bank: 3-mile reach, the center of which is 2½ miles below the gauge; bank is straight, mostly cultivated, some caving; old levee will average about one-eighth mile back; at flood stage water probably flows over banks into low ground back and into White River Basin.
	*190.7	1.0	Right bank: 4½-mile reach, the center of which is 6½ miles above the gauge; bank concave at upper end, convex below; about one-half cultivated, the rest woods; mouth of St. Francis River is at upper end of the reach; Porter Lake and low ground back of central and lower part of the reach; sand-bar in front of the lower end of the reach; some caving; at central 2½ miles of the reach contours show that at flood stages the water flows over the bank into Porter Lake.
Mouth White River:			
Mean high water above Memphis datum 1872–1889, inclusive. †160.9 feet.	159.8	1.1	Right bank: 3-mile reach; gauge about center of reach; bank straight; lower part of reach caving somewhat; willows for 1 mile at upper end; about 1 mile cultivated and the rest wooded; no levees; mouth of White River about 1½ miles above the gauge.
Extreme high water above Memphis datum, 164.0 feet.	160.3	0.6	Left bank: 3-mile reach; opposite the gauge; bank convex some caving; mostly cultivated; old levee near bank for 1 mile at upper end; levee below that averages about 1 mile back; probably at flood stages the water flows over bank on 1 mile of this reach and across a point.
	‡160.4	0.5	Right bank: 4-mile reach, the center of which is 2½ miles below the gauge; bank slightly concave; caving rapidly; no levee; about two-fifths of the reach cultivated, the rest wooded; contours indicate that at flood stages the water flows diagonally over the bank back to low ground.
	‡159.4	1.5	Right bank: 3½-mile reach, the center of which is 5 miles above the gauge; bank nearly straight; mostly wooded; caving somewhat; water apparently flows over bank of lower one-half of the reach and back into White River. This reach taken to see if the White River had apparently the effect of decreasing normal height of bank immediately below its mouth.
Lake Providence:			
Mean high water above Memphis datum 1872–1889, inclusive, 113 feet.	112.4	0.6	Right bank: 3-mile reach, gauge at center of reach; bank slightly convex; caving a little; cultivated; levee near bank; elevations on each side of levee used in getting the mean.
Extreme high water above Memphis datum, 114.9 feet.	112.5	0.5	Left bank: 3-mile reach opposite the gauge; bank slightly concave; cultivated; levee near bank; elevations on each side of the levee were used in getting the mean; sand-bars in front of most of the reach.

*A slope correction applied to get this result found by taking mean of H. W. slopes for 1880, 1882–1884, inclusive, and 1886–1888, inclusive.

†No record for 1878 and 1879, so that they are not included in this mean.

‡A slope correction used in getting these results found by taking mean H. W. slope for 1880, 1882–1884, inclusive, and 1886–1888, inclusive.

Locality.	Mean elevation of banks above Memphis datum.	Differences—mean bank and mean high-water elevations.	Remarks.
	Feet.	*Feet.*	
Vicksburg:			
Mean high water above Memphis datum 1872–1889, inclusive, 95.8 feet.	96.6	—0.8	Right bank: 3-mile reach on Delta Point opposite the gauge; bank around a sharp point; rapidly caving on upper side; not caving on lower side; levee near lower main bank; a new bank built out from lower side of point covered with willows; has some elevations nearly as high as main bank; several levees run across the point; main bank cultivated.
Extreme high water above Memphis datum, 101.9 feet.	94.0	1.8	Left bank: 1½-mile reach, lying below the gauge; bluffs along bank prevent using elevations above the gauge; bank cultivated; not caving; bluffs average one-fourth back of this reach.
	*95.3	0.5	Right bank: 3-mile reach, the center of which is 4½ miles below the gauge; bank nearly straight; new levee (not all built at time survey was made) is one-fourth mile back; cultivated; some caving; contours indicate that at flood stages water flows over bank of the lower mile of this reach into low ground.
	*99.8	—4.0	Left bank: 3-mile reach, the center of which is 4½ miles below the gauge; bank nearly straight; bluffs and railroad back about 1 mile; cultivated; not caving; sand-bar in front; old levee one-fourth mile back at lower end; Big Bayou empties into river at lower end of the reach.
Natchez:			
Mean high water above Memphis datum 1872–1889, inclusive, 66 feet.	70.1	—4.1	Right bank: 3 mile reach opposite the gauge; bank convex; cultivated; not caving; levee near the bank; elevations each side of the levee used in getting the mean.
Extreme high water above Memphis datum, 71.5 feet.	*68.4	—2.4	Right bank: 3-mile reach, the center of which is 3 miles below the gauge; bank slightly convex, some caving; cultivated; levee near bank, elevations each side of the levee taken in getting the mean.
	*70.6	—4.8	Left bank: 3-mile reach, the center of which is 3 miles below the gauge; bank slightly concave, slowly caving; cultivated except for about one-fourth mile at the upper end, which is woods and thick vines; no levee; bluffs run back from bank above upper end of reach, and at upper end are one-fourth mile back.
Red River Landing:			
Mean high water above Memphis datum 1872–1889, inclusive, 52.6 feet.	52.2	0.4	Right bank: 3-mile reach, the gauge being about the center of the reach; bank nearly straight; slight caving; cultivated above the gauge and woods below; levee averages about one-fourth mile back; low ground and lakes lie within 1 mile back of bank. Mouth of Red River 1½ miles above gauge.
Extreme high water above Memphis datum, 59.2 feet.	55.7	—3.1	Left bank: 3-mile reach opposite the gauge; bank convex; wooded; not caving; levee at lower end and about 1 mile back; contours indicate that above this reach the water at flood stages flows over the bank and across the point, passing this reach nearly parallel with the shore.
Baton Rouge:			
Mean high water above Memphis datum 1872–1889, inclusive, 38.7 feet.	38.7	0.0	Right bank: 3 mile reach opposite the gauge; bank nearly straight, slightly convex at lower end; some caving; cultivated; old levee near bank; elevations on each side of levee used.
Extreme high water above Memphis datum, 43.1 feet.	39.2	—0.5	Left bank: 2-mile stretch; 1½ miles of it lies below the gauge. Bank slightly concave; no caving; cultivated; old levee near bank; elevations each side of levee used; bluffs back of upper part of reach.

* A slope correction applied to get these results found by taking mean of H. W. slopes for 1880, 1882–1884, inclusive, and 1886–1888, inclusive.

Locality.	Mean elevation of banks above Memphis datum.	Differences—mean bank and mean high-water elevations.	Remarks.
Fulton:	*Feet.*	*Feet.*	
Mean high water above Memphis datum 1872–1889, inclusive, 248.5 feet.*	251.2	—2.7	Right bank: 3-mile reach opposite the gauge; bank is nearly straight; but little caving; mostly cultivated; levee near bank; high water coming across a point apparently empties into the river just above this reach; a wide gap in the levee just above the head of this reach; elevations each side of the levee used.
Extreme high water above Memphis datum, 252.11 feet.	251.4	—2.9	Left bank: 3-mile reach, the center of which is 3 miles below the gauge; bank nearly straight; about two-thirds cultivated, the rest wooded; not caving; bluffs run back from shore at the upper end of the reach; mouth of Hatchee River near lower end of the reach, and head of chute of Hatchee Island at lower end of reach; no levee.
Arkansas City:			
Mean high water above Memphis datum, 147.3 feet.†	146.6	0.7	Right bank: 3-mile reach, gauge at center of reach; bank concave on lower 2 miles of reach; upper mile convex and lies back of Island 78; railroad and levee near bank; upper 1½ miles cultivated, rest of reach wooded; some caving on lower 1½ miles of the reach.
Extreme high water above Memphis datum, 150.22 feet.	145.8	1.5	Left bank: 3-mile reach opposite the gauge; bank convex; about one-half the reach cultivated, the rest wooded; levee close to bank for upper 1½ miles of the reach, and averages one-fourth mile back of lower 1½ miles of the reach; but little if any caving; contours would indicate that over the central 1½ miles of this reach the water flows over the bank and across a point at flood stages.
Greenville:			
Mean high water above Memphis datum 1872–1889, inclusive, 134.3 feet.‡	133.6	0.7	Right bank: 3-mile reach opposite the gauge; bank partly concave, partly convex; the reach lies on the lower side of a point; all except the upper mile of the reach lies behind a tow-head; but little caving; wooded; no levee.
Extreme high water above Memphis datum, 136.55 feet.	134.3	0.0	Left bank: 3-mile reach; gauge at center of the reach; bank concave; caving rapidly; about three-eighths of the reach cultivated, the rest wooded; levee and railroad average about one-eighth mile back.
St. Joseph, La:			
Mean high water above Memphis datum 1872–1889, inclusive, 79.4 feet.§	79.3	0.1	Right bank: 3-mile reach; gauge at center of the reach; bank slightly concave; one-half cultivated, the rest wooded; but little if any caving; levee will average one-eighth mile back; upper half of reach is cultivated, but lies back of a willow bar.
Extreme high water above Memphis datum, 84.51 feet.	81.0	—1.6	Left bank: 3-mile reach opposite the gauge; bank convex; sand-bar at lower half of the reach; not caving; mostly cultivated; no levee.
Port Hickey:			
Mean high water above Memphis datum 1872–1889, inclusive, 42.7 feet.‖	43.9	—1.2	Right bank: 3 mile reach opposite the gauge; bank very convex; takes in a sharp point; caving on the upper side of the point 100 feet yearly; no caving on lower half of the reach; two-thirds cultivated, the rest wooded; levee will average less than one-eighth mile back of the bank; elevations each side of the levee taken; cypress swamp back of the reach, average a little over one-half mile back.
Extreme high water above Memphis datum, 48.45 feet.	¶45.9	—3.2	Left bank: 2-mile reach, the center of which is 3½ miles above the gauge; bank convex; upper half cultivated, rest wooded; not caving; no levee.
	¶46.1	—3.4	Left bank: 2-mile reach, the center of which is 2½ miles below the gauge; bank slightly convex; cultivated; no levee; bluffs about one-eighth mile back of upper one-half mile, then bluffs run directly back from river; lake and swamp back of the rest of the reach.

* Mean of eighteen years derived from Memphis.
† Mean of sixteen years derived from mouth of White River.
‡ Mean of eighteen years derived from Lake Providence.
§ Mean of eighteen years derived from Vicksburg.
‖ Mean of eighteen years derived from Baton Rouge. Mean of six years at Port Hickey is 45.40.
¶ A slope correction applied in getting these results found by taking mean of H. W. slopes for 1880, 1883–1884, inclusive, and 1886–1888, inclusive.

Results of discharge observations, Mississippi River, Old River, and Bayou des Glaises.

Station.	Date.	Gauge.		Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	Method.	Remarks.
		Reading.	Rise or fall in preceding 24 hours.	Area.		Depth.			Width.						
				Water.	Below datum.	Mean	Mean datum.	Maximum.							
	1884.	*Feet.*	*Feet.*	*Sq. ft.*	*Sq. ft.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. ft.*	*Feet.*	*Cu. ft.*			
Hays' Landing, Miss.	Feb. 18	35.31	+0.50	159,481	.....	56.8	.....	84.0	2,810	.....	7.496	1,195,493	.....	Meter	Results of other discharge observations at this station are published as follows: Jan. 1 to Nov. 25, 1882: gauge-reading from 6.05 to 38.59 feet. Rep. M. R. C., 1883, p. 222. Floods of 1882: gauge-reading 34.14 to 38.58 feet. Rep. M. R. C., 1884, p. 81. Mar. 16, 1884: gauge reading 37.72 feet. Rep. M. R. C., 1884, p. 116.
Through Waterproof Cut-off.	May 25	†40.68	—0.08	72,700	72,700	51.9	51.9	73.0	1,401	.....	*6.455	469,300	.....	Meter.	The discharges through the old channel were observed about the same times, and computed to be 370,465 cubic feet per second in May, and 231,174 cubic feet per second in July.
	July '23	21.02	—0.33	75,199	101,484	59.1	72.5	110.0	1,273	+28,784	†4.047	304,296	.....	‖ D. F	
	1882.														
Old River, one-quarter mile above the mouth.	Jan. 9	34.61	+0.45	23,461	24,794	26.4	26.9	35.7	890	.....	2.257	76,400	VI—4	...do ..	All these gauge-readings were apparently on the Red River Landing gauge. In computing the velocities **no corrections have been made for the departures of the floats from the** normal to the discharge section, because these departures were small and in both directions.
	Jan. 11	35.10	+0.40	23,212	24,112	25.4	26.1	37.0	913	— 682	3.248	75,382	.....	...do ..	
	Jan. 16	36.08	+0.15	22,389	22,389	24.3	24.3	38.7	923	— 1,723	2.592	58,031	XII—4	...do ..	
Bayou des Glaises, Hamburg, La.	Apr. 4	§49.30	—0.10	5,920	.....	18.5	.....	.....	320	.....	2.233	13,220	VI—2	Meter.	Results of other discharge observations at this station are published as follows: Oct. 1884, to Mar. 1885: gauge-reading from 13.61 to 42.41 feet. Rep. M. R. C., 1887, p. 2854. According to the daily log-book and reports these observations were taken Apr. 4, but the results given above were tabulated under Apr. 5. As the field notes could not be obtained, no recomputation has been made.

* The velocity observations were taken about 100 feet above the section sounded. Water surface was 87.326 feet above the Cairo datum plane.
† In computing the velocities the average departure of the floats, 46.5 feet, was assumed for each path.
‡ St. Joseph gauge. ‖ Double float. § Barbre's Landing gauge.

EXTRACTS FROM REPORT BY MR. WILLIAM GERIG, ASSISTANT ENGINEER, CHIEF OF PARTY, UPON DISCHARGE OBSERVATIONS, MISSISSIPPI RIVER, NEAR NEW MADRID, MISSOURI, 1888–'89, AND UPON THE OFFICE COMPUTATION.

MEMPHIS, TENN., *September* 5, 1889.

* * * * * * *

The party at this station consisted of one assistant engineer, one steam engineer, one steersman, and two boatmen.

Observations were made upon two sections about 1¼ miles apart. The first was called the high-water section, and was about 5 miles below New Madrid. At the end of the section on the right bank a base-line 4,829 feet long was measured nearly at right angles to the section. On each bank a series of radial signals was set, determining lines which intersected the section at points 300 feet apart called velocity stations. Signals were also set on the section to determine the river width; the distance between these signals being 6,053 feet. Distances from the water's edge to these signals were observed each day which determined the river width. In the system of intersecting ranges, on the right bank, the pivot signal was 5,302 feet from the section and a perpendicular from it intersected the section 1,084 feet from signal "B" on the prolonged section. The other signals were placed between the pivot signal and section and on the base-line. Secondary signals were set between them to locate the soundings.

As the lower stages of the river were reached in December, several undesirable features developed in the high-water section, the presence of bars near both banks made the water too shallow to allow the launch to be used, and caused the current to be deflected toward the middle of the river so that it was no longer normal to the section; as the water continued falling the bars appeared and a pocket was formed near the left bank in which there was no current. It was decided, therefore, to change the section, and a low-water section was located about 1¼ miles above the high-water section.

The manner of locating velocity and sounding stations was similar to that of the high-water section. The points at the end of this section were designated "Z" and "X," and the distance between them was 4,141.8 feet. The pivot signal was on the left bank and at a perpendicular distance from the prolonged section-line of 1,638 feet; the intersecting point was 1,147 feet from "X," the minimum angle for locating the section being 30° 45′.

The river rose in January, and on the 19th the high-water section was occupied and used till February 13 and then the low-water section till February 22.

The instruments in use consisted of Price meter No. 10, a Morse register, a break circuit clock, electric batteries, transit, level, sounding leads, lines, etc. The meter was the well-known Price meter, which had been in use on the river for several years. * * * The meter gave no trouble except once when the gutta-percha which made the break had worn down so that the electric current was not broken. The gutta-percha was removed, as well as the other pieces which held it in position, and then the contact was made on the remaining half of the axis. * * *

Much trouble was caused by the clock, which was a very old one and was frequently out of repair, at which times a watch was used, the time of beginning being marked on the ribbon with a pencil and also that of ending. * * *

The meter circuit was made through a steel sash-cord on which the meter was sus-suspended, and through an insulated copper wire which was paid out with the sash-cord. A 15-pound sounding lead and a ⅜-inch cotton line were used throughout the season.

Drifting soundings were taken during the highest water, but generally soundings were taken without drifting, since the maximum depth was about 30 feet.

The meter was suspended from a boom 12 feet long at the stern of the launch, the boom projecting over the side and making an angle of about 60° down-stream with the axis of the launch. A steel sash-cord $\frac{3}{16}$-inch diameter passed around a reel in stern of launch, through a small pulley in the end of boom, thence to an iron rod 1 inch in diameter and 2 feet long. To this rod the meter was attached, and also a lead weight of about 50 pounds. Attached to the top of the rod was a fine steel piano wire, which passed through a pulley in the end of a 20-foot boom in the bow of the launch and thence to a reel. By paying out proper lengths of standing and guy lines the meter could be immersed to any desired depth. * * *

The coefficients to be used in reducing the registrations of the meter to velocity in feet per second were determined by causing the meter to move through still water over a known distance at various velocities, the time and number of registrations being noted. A float was anchored in still water, upon which a beam was revolved, at the end of which the meter was attached. The beam was of such a length that in making one revolution the meter traversed 100 feet. The meter circuit was made from the battery to the stand on which the arm was revolved, thence to the meter,

thence back by a copper wire through the register to the other pole of the battery. The clock circuit was so arranged that when the revolving arm arrived at a certain point the circuit was made and the time registered until the arm had made a revolution, when the circuit was broken and the time ceased to be recorded. This was done by a small brass arm extending up so that the revolving arm could touch it and move it till it touched another piece of brass or nickel and thus made the connection. By this method time of beginning and ending could easily be measured to one-twentieth of a second if the connection was made during the half second when the circuit was made; otherwise it could only be measured to the nearest half second. The revolutions of the meter could be measured equally as accurately. * * *

The rating observations were reduced by the method of least squares. The following are the results of the rating of the meter which were adopted for use:

Date.	No. of observations.	a	b	Mean error of observations.
Nov. 23, 1888	22	3.860	+0.215	±0.018
Apr. 17, 1889	38	3.920	+0.100	±0.020

A number of ratings were made but rejected on account of large errors which were due to the swivel not turning on its axis in changing the direction of the revolution of the arm, and thereby causing the revolutions of the meter to be retarded, and also that the brass connections upon which the arm revolved were nearly worn out, so that false registrations were made; on April 17 all these errors were eliminated and the results are very accurate.

The formulæ used in reducing were, till December 31, 1888,

$$y = 3.86\,x + 0.22, \text{ and afterwards } y = 3.92\,x + 0.10.$$

The lead line was tested every morning before using and corrected by retagging if in error. It was also tested at close of work and errors, if any, compensated by correction of soundings.

The number of seconds that the meter continued to spin was noted before and after each day's work, and the mean recorded. * * *

In the final reduction the widths were calculated and the soundings plotted on cross-section sheets, as were also the velocities. The velocities were reduced by the formulæ adopted and recorded in the note-books. The total area was divided into partial areas of 500 feet width; these partial areas were calculated by counting the squares and were multiplied by the mean velocities of the partial areas which were taken from the cross-section sheets. The product was the partial discharge, and the sum of the partial discharges gave the total discharge, and this divided by the total area gave the mean velocity. The counting of the registrations was done in the field and checked after each day's work.

The measurements for velocity were taken at six-tenths depth. The length of the observations varied from 150 seconds to 300 seconds, though generally the duration was 150 seconds. The computation of velocities from the given times and registrations was performed by means of the tables prepared for the purpose. The results of computation were copied in a tabular form accompanying this report and also into the note-books.

The gauge-readings correspond to the mean time of observation. The gauge was read at the time of beginning and ending of each day's work, which was about 8 a. m. and 4 p. m. The rise or fall in twenty-four hours is the difference in the mean gauge-reading for that day and the preceding one.

The computation of datum areas has been made in the following manner: For the high-water section the datum was assumed to correspond to the gauge-reading of 25.6 feet. The datum width was taken as 5,967 feet, that being the measured width and gauge-reading on February 27, 1889. The slope of the banks down to 20 feet on gauge was uniform, also from 20 feet to 10 feet and below 10 feet, and the datum areas have been computed by the formala:

$$\text{Datum area} = (25.6 - h)\,\frac{5967 + w}{2} + \text{water area},$$

where h = gauge and w = width.

NOTE.—For a full description of the meter and outfit and the methods of computation, see Annual Report Chief of Engineers, 1887, pages 2821–2823. (Secretary Mississippi River Commission.)

The formula between 20 feet and 10 feet on gauge becomes:

$$\text{Datum area} = (25.6 - 20)\frac{5967 + 5930}{2} + (20 - h)\frac{5930 + w}{2} + \text{water area}$$

$$= 33312 + (20 - h)\frac{5930 + w}{2} + \text{water area},$$

in which 5,930 feet is width at 20-foot stage.

For stages below 10 feet the formula is:

$$\text{Datum area} = 33312 + (20 - 10)\frac{5930 + 5820}{2} + (10 - h)\frac{5820 + w}{2} + \text{water area}$$

$$= 9206.2 + (10 - h)\frac{5820 + w}{2} + \text{water area}.$$

The low-water section datum was assumed as the surface of the water on January 18, the gauge-reading being 21 62. The width on that day was 4,023 feet, which was taken as the datum width. The slope of the banks change at 20 feet. 15 feet, and 10 feet stages, and the widths at these stages are 4,009 feet, 3,965 feet, and 3,911 feet. The formula used is:

$$\text{Datum area} = (21.62 - h)\frac{4023 + w}{2} + \text{water area}.$$

Between stages 15 feet and 20 feet the formula becomes:

$$\text{Datum area} = (21.62 - 20)\frac{4023 + 4009}{2} + 20 - h)\frac{4009 + w}{2} + \text{water area}.$$

$$= 6506 + (20 - h) + \frac{4009 + w}{2} + \text{water area}.$$

Between 15 feet and 10 feet:

$$\text{Datum area} = 6506 + (20 - 15)\frac{4009 + 3965}{2} + (15 - h)\frac{3965 + w}{2} + \text{water area}$$

$$= 26441 + (15 - h)\frac{3965 + w}{2} + \text{water area}.$$

Below 10 feet:

$$\text{Datum area} = 26441 + (15 - 10)\frac{3965 + 3911}{2} + (10 - h)\frac{3911 + w}{2} + \text{water area}$$

$$= 46131 + (10 - h)\frac{3911 + w}{2} + \text{water area}.$$

Mean depth has been obtained by dividing the water area by the width, and mean datum depth has been obtained by dividing the datum area by the datum width. Maximum depth was taken directly from the notes. Scour or fill has been obtained by taking the difference of the datum areas; scour is indicated by the positive sign.

The direction of the wind is indicated by dividing the horizon into twelve parts and numbering the parts the same as the hours on a clock dial, XII being up-stream and indicating a down-stream wind.

A plot has been made with the mean velocities and discharges of both sections as ordinates and the gauge heights as abscissas. The scales for each system are shown on the plot. * * *

Herewith also find a tracing showing the location of the sections.

The entire work has been checked in various ways and great care has been taken to eliminate all errors of computation.

* * * * * * *

Capt. SMITH S. LEACH,
Corps of Engineers, U. S. A.,
Memphis, Tenn.

*Results of discharge observations, Mississippi River, New Madrid, Missouri, 1888–1889.**

METHOD.—Meter at six-tenths depth from the surface.

Date.	Gauge.		Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.
	Reading.	Rise or fall in the preceding 24 hours.†	Area.		Depth.			Width.				
			Water.	Below datum.	Mean.	Mean datum.	Maximum.					
1888.	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*	
Nov. 28	18.50						30.0	5,915				1—Slight.
29	17.30	—1.20					28.0	5,913				XII—Slight.
30	16.30	—1.00					31.0	5,908				XII—Strong.
Dec. 1	15.25	—1.05	125,650	187,068	21.3	31.3	30.0	5,905		3.460	434,751	X—Slight.
3	12.80	—2.45	112,320	188,147	19.1	31.5	29.6	5,880	+1,079	3.383	379,995	X—Slight.
4	12.05	—0.75	103,004	183,237	17.5	30.7	29.0	5,873	—4,910	3.255	335,220	IX—Slight.
5	11.30	—0.75	100,195	184,837	17.1	31.0	28.0	5,870	+1,600	3.219	322,582	XI—Strong.
6	10.35	—0.95	97,415	187,642	16.6	31.4	26.0	5,865	+2,805	3.140	305,854	VIII—Mild.
7	9.70	—0.65	94,500	188,330	16.4	31.6	25.5	5,772	+ 688	3.234	305,577	V—Strong.
8	9.20	—0.50	89,840	186,493	15.8	31.3	25.0	5,657	—1,837	3.164	284,209	VI—Slight.
10	8.62	—0.57	84,200	183,879	16.6	30.8	23.0	5,301	—2,614	3.076	247,362	II—Mild.
11	8.32	—0.30	80,146	181,491	16.0	30.4	22.5	5,275	—2,378	3.082	235,283	XII—Mild.
12	8.04	—0.29	75,867	178,907	15.2	30.1	22.5	5,267	—2,584	3.129	223,009	XII—Mild.
13	7.74	—0.30	73,910	128,844	19.1	32.0	26.0	3,868	(‡)	2.951	218,082	XII—Mild.
14	7.44	—0.30	73,190	129,285	19.2	32.1	25.0	3,866	+ 441	2.983	218,359	V—Strong.
15	7.20	—0.24	73,125	130,145	19.0	32.3	25.0	3,866	+ 860	3.030	221,208	V—Very strong.
17	6.90	—0.30	72,820	131,000	18.8	32.6	25.5	3,863	+ 855	2.950	214,623	XI—Strong.
18	6.90	0.00	75,258	133,438	19.5	33.2	26.5	3,862	+2,438	2.890	217,282	X—Slight.
19	7.00	+0.10	74,226	132,021	19.2	32.8	26.0	3,864	—1,417	2.950	218,922	XII—Slight.
20	7.19	+0.19	75,760	132,825	19.6	33.0	25.5	3,864	+ 804	2.975	225,394	VII—Strong.
21	7.47	+0.29	75,935	131,883	19.7	32.7	26.0	3,865	— 942	3.020	229,446	XI—Mild.
22	8.15	+0.67	78,545	131,880	20.3	32.7	26.7	3,878	— 3	3.040	238,743	VIII—Mild.
24	8.90	+0.75	82,015	132,436	21.1	32.9	27.5	3,890	+ 556	3.177	260,486	VI—Mild.
25	9.13	+0.23	85,090	134,617	21.8	33.5	27.5	3,895	+2,181	3.200	271,930	Calm.
26	9.26	+0.13										VI—Very strong.
27	9.62	+0.26	85,296	132,907	21.8	33.0	28.0	3,908	—1,710	3.221	274,733	X—Slight.
28	10.23	+0.61	87,705	132,935	22.4	33.0	28.3	3,913	+ 28	3.290	288,182	Calm.
29	10.85	+0.62	89,895	132,691	22.9	33.0	30.0	3,917	— 244	3.360	301,806	Calm.
31	12.08	+1.23	95,305	133,283	24.2	33.1	31.0	3,935	+ 592	3.418	325,708	XII—Mild.

* From reduction at office of first district engineer.
† Where a day is omitted the rise or fall given on the following day is for 48 hours.
‡ Low-water section occupied from December 13 to January 18, and from February 14 to 21, inclusive.

Results of discharge observations, Mississippi River, New Madrid, Missouri, 1888–1889*—Continued.

METHOD.—Meter at six-tenths depth from the surface.

Date.	Gauge.		Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.
	Reading.	Rise or fall in the preceding 24 hours.†	Area.		Depth.			Width.				
			Water.	Below datum.	Mean.	Mean datum.	Maximum.					
1889.	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*	
Jan. 1	12.20	—0.12	97,375	134,879	24.7	33.5	32.1	3,933	+1,596	3.450	335,947	XII—Mild.
2	12.13	—0.07	97,150	134,927	24.7	33.5	32.0	3,936	+ 48	3.416	331,898	VI—Mild.
3	11.91	—0.22	96,690	135,346	24.6	33.6	31.5	3,934	+ 419	3.355	324,366	Calm.
4	11.39	—0.52	93,330	134,016	23.8	33.3	30.5	3,926	—1,330	3.316	309,476	V—Mild.
5	10.98	—0.41	92,005	134,305	23.4	33.4	29.5	3,924	+ 289	3.300	303,524	X—Slight.
7	11.17	+0.19	91,940	133,486	23.5	33.2	29.5	3,922	— 819	3.335	306,580	V—Slight.
8	11.60	+0.43	93,645	133,502	23.9	33.2	30.0	3,926	+ 16	3.380	316,141	V—Strong.
10	13.35	+1.75	99,765	132,735	25.3	33.0	32.0	3,949	— 767	3.560	354,724	VI—Slight.
11	14.95	+1.60	104,925	131,594	26.5	32.7	32.5	3,965	—1,141	3.650	383,172	XI—Slight.
12	16.93	+2.00	111,295	129,983	28.0	32.3	34.0	3,979	—1,611	3.990	444,401	V—Slight.
14	19.75	+2.80	124,350	131,858	30.7	32.7	38.0	4,007	+1,875	4.500	558,883	Calm.
15	20.28	+0.53	128,900	134,281	32.1	33.4	38.7	4,010	+2,423	4.465	575,539	V—Strong.
16	20.57	+0.29	.....	.....	.....	.....	.....	4,014	.....	.....	.....	V—Very strong.
17	20.97	+0.40	130,205	132,817	32.4	33.0	40.0	4,015	—1,464	4.580	595,303	XII—Slight.
18	21.62	+0.65	133,155	133,155	33.1	33.1	40.0	4,023	+ 338	4.540	605,016	XII—Slight.
19	22.20	+0.58	169,950	190,210	28.5	31.9	37.0	5,951	.....	3.810	645,953	XII—Mild.
21	24.10	+1.90	177,085	186,026	29.7	31.2	37.5	5,955	—4,184	3.906	691,550	XII—Mild.
22	24.58	+0.43	178,255	184,635	30.0	30.9	38.0	5,959	—1,891	3.940	702,290	VI—Strong.
23	24.15	—0.38	175,895	184,539	29.5	30.9	37.0	5,955	— 96	3.930	692,823	Calm.
24	23.35	—0.80	173,840	187,249	29.2	31.4	38.0	5,952	+2,710	3.850	670,076	XII—Slight.
25	22.20	—1.15	168,820	189,065	28.4	31.7	37.4	5,942	+1,816	3.820	644,886	Calm.
26	20.90	—1.30	159,105	187,075	27.0	31.4	35.0	5,936	—1,990	3.720	591,046	XII—Slight.
28	18.85	—2.05	146,960	187,087	24.8	31.4	33.0	5,923	+ 12	3.625	532,707	XI—Slight.
29	18.65	—0.20	145,330	186,641	24.5	31.3	32.3	5,923	— 446	3.564	518,893	XI—Slight.
30	19.10	+0.55	145,870	184,516	24.6	30.9	33.5	5,925	—2,125	3.624	528,652	XII—Strong.
31	19.93	+0.83	150,285	184,012	25.3	30.8	33.5	5,930	— 504	3.695	555,262	XI—Strong.
Feb 1	20.60	+0.67	156,050	185,805	26.3	31.1	35.0	5,935	+1,793	3.690	574,319	V—Mild.
2	21.38	+0.78	161,040	186,187	27.1	31.2	34.5	5,940	+ 382	3.718	597,961	Calm.
4	22.45	+1.07	166,745	185,509	28.0	31.1	34.8	5,946	— 678	3.830	638,696	VIII—Strong.
5	22.48	+0.03	166,785	185,327	28.0	31.1	35.3	5,951	— 182	3.837	639,729	XI—Strong.
6	22.03	—0.45	164,820	186,092	27.7	31.2	35.0	5,950	+ 765	3.830	631,680	XI—Mild.
7	21.12	—0.91	158,255	184,916	26.7	31.0	34.3	5,936	—1,174	3.678	612,827	VII—Strong.
8	19.90	—1.22	148,855	182,759	25.1	30.6	32.5	5,926	—2,159	3.590	534,501	VI—Mild.

* From reduction at office of first district engineer.

† Where a day is omitted the rise or fall given on the following day is for 48 hours.

	9	18.75	−1.15	143,375	184,115	25.9	30.9	32.0	5,917	+1,356	3.547	508,610	XII—Mild.
	11	16.53	−2.22	125,460	179,366	21.8	30.1	29.5	5,902	−4,749	3.463	424,511	XI—Strong.
	12	15.50	−1.03	114,860	174,776	19.5	29.8	29.0	5,894	−4,593	3.398	387,841	X—Mild.
	13	13.90	−1.60	110,025	179,375	18.7	30.1	28.0	5,887	+4,599	3.391	373,143	VIII—Strong.
	14	12.15	−1.85	.....	.....	.....	.....	.....	3,932	*	.....	.....	Fog.
	15	11.30	−0.85	.....	.....	.....	.....	.....	.....	.....	.....	.....	Fog.
	16	10.53	−0.77	84,805	128,880	21.6	32.0	28.0	3,925	.....	4.481	295,178	VIII—Slight.
	18	10.00	−0.53	84,370	130,501	21.5	32.4	27.7	3,914	+1,621	3.483	296,364	X—Moderate.
	19	11.55	+1.55	88,325	128,880	22.7	32.0	29.0	3,926	−1,621	3.536	314,101	X—Slight.
	20	14.75	+3.20	104,170	131,602	26.3	32.7	32.7	3,935	+2,722	3.961	414,847	VI—Slight.
	21	18.30	+3.55	118,205	131,517	29.6	32.7	36.0	3,998	− 85	4.392	519,182	VI—Slight.
	22	20.75	+2.45	153,535	182,390	25.9	30.6	34.0	5,930	.....	3.815	585,687	XII—Slight.
	23	22.40	+1.65	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	24	23.80	+1.40	170,565	181,295	29.0	30.4	36.0	5,956	−1,095	4.000	682,280	III—Slight.
	25	25.10	+1.30	178,795	181,779	30.0	30.4	38.0	5,965	+ 484	4.031	720,636	II—Slight.
	26	25.60	+0.50	185,910	185,910	31.2	31.2	39.0	5,966	+4,131	4.057	754,336	Calm.
	27	25.60	0.00	187,650	187,650	31.5	31.5	39.0	5,967	+1,740	4.055	760,839	VI—Slight.
	28	25.35	−0.25	187,460	188,953	31.4	31.7	39.5	5,967	+1,302	4.000	749,665	XI—Slight.
Mar.	1	25.00	−0.35	188,670	187,249	30.8	31.4	38.8	5,962	−1,708	4.009	736,346	XII—Slight.
	2	24.35	−0.65	179,040	186,499	30.0	31.2	38.0	5,958	− 750	3.949	705,626	I—Slight.
	4	22.90	−1.45	168,000	184,087	28.3	30.9	38.0	5,948	−2,412	3.855	647,936	I—Slight.
	5	22.70	−0.20	167,240	184,515	28.1	30.9	37.0	5,947	+ 438	3.826	639,933	XI—Mild.
	6	22.70	−0.00	166,825	184,100	28.0	30.9	37.5	5,947	− 415	3.837	640,172	XII—Slight.
	7	22.65	−0.05	167,410	184,983	28.2	31.0	36.7	5,947	+ 883	3.819	639,283	XII—Slight.
	8	22.45	−0.20	165,975	184,740	27.9	31.0	38.0	5,944	− 243	3.770	624,933	XI—Mild.
	9	21.70	−0.75	163,380	186,589	27.5	31.3	37.5	5,934	+1,849	3.751	612,793	XI—Mild.
	11	20.23	−1.47	155,045	186,980	26.2	31.4	35.7	5,927	+ 391	3.651	566,100	VI—Slight.
	12	19.65	−0.58	149,510	184,897	25.2	31.0	35.3	5,928	−2,088	3.638	543,910	XII—Slight.
	13	19.10	−0.55	145,840	184,483	24.7	30.9	34.7	5,918	− 414	3.628	528,894	VI—Slight.
	14	18.80	−0.30	143,645	184,064	24.3	30.8	34.0	5,915	− 419	3.614	519,161	VI—Slight.
	15	18.40	−0.40	141,630	184,417	24.0	30.9	33.7	5,914	+ 353	3.559	504,059	VI—Slight.
	16	17.95	−0.45	139,050	184,500	23.6	30.9	32.7	5,912	+ 83	3.547	493,232	VI—Slight.
	18	17.23	−0.72	131,590	181,404	22.3	30.4	32.0	5,905	−3,096	3.529	463,943	VI—Slight.
	19	16.70	−0.53	129,920	182,758	22.0	30.6	31.8	5,904	+1,354	3.602	467,779	XII—Strong.
	20	16.50	−0.20	127,375	181,393	21.6	30.4	31.0	5,902	−1,365	3.439	457,374	XII—Mild.
	21	16.25	−0.25	125,350	180,843	21.3	30.3	31.5	5,900	− 559	3.402	426,471	XII—Slight.
	22	16.18	−0.07	125,115	180,636	21.2	30.3	30.5	5,898	− 207	3.392	424,272	III—Slight.
	23	16.75	+0.57	128,280	180,818	21.7	30.3	31.0	5,902	+ 182	3.455	443,187	XII—Slight.
	25	18.95	+2.20	141,290	180,822	23.9	30.3	33.0	5,919	+ 4	3.598	508,276	I—Slight.
	26	19.37	+0.42	144,300	181,346	24.4	30.4	33.7	5,925	+ 524	3.690	531,697	VI—Slight.
	27	19.35	−0.02	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	28	19.05	−0.30	143,530	182,473	24.2	30.6	33.3	5,925	+1,127	3.673	527,208	X—Slight.
	29	18.63	−0.42	141,100	182,529	23.8	30.6	33.5	5,920	+ 56	3.672	518,984	VI—Moderate.
	30	18.03	−0.60	137,770	182,747	23.3	30.6	32.0	5,913	+ 218	3.618	498,321	XII—Slight.
Apr.	1	17.27	−0.76	131,305	180,777	22.2	30.3	31.5	5,909	−1,970	3.573	469,445	XII—Strong.
	2	16.78	−0.49	128,520	180,898	21.7	30.3	31.0	5,901	+ 103	3.441	442,305	XII—Slight.
	3	16.30	−0.48	126,100	181,289	21.4	30.6	30.3	5,896	+ 409	3.463	436,737	XII—Slight.
	4	16.10	−0.20	123,200	179,572	20.9	30.1	30.3	5,896	−1,717	3.420	421,334	XII—Slight.
	5	16.08	−0.02	123,100	179,591	21.4	30.1	30.3	5,896	+ 19	3.424	421,725	VI—Mild.
	6	16.18	+0.10	123,220	179,119	20.9	30.0	30.3	5,896	− 472	3.441	424,003	I—Mild.
	8	16.23	+0.05	123,355	179,460	21.0	30.0	30.5	5,897	+ 341	3.439	425,915	VI—Slight.
	9	15.88	−0.35	122,942	180,611	20.9	30.3	30.5	5,894	+1,151	3.418	420,261	VI—Slight.

Results of discharge observations, Mississippi River, New Madrid, Missouri, 1888–1889*—Continued.

METHOD.—Meter at sixth-tenths depth from the surface.

Date.	Gauge.		Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.
	Reading.	Rise or fall in the preceding 24 hours.†	Area.		Depth.			Width.				
			Water.	Below datum.	Mean.	Mean datum.	Maximum.					
1889.	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*	
Apr. 10	15.47	—0.41	120,450	190,538	20.4	30.2	30.8	5,892	— 73	3.383	407,431	VI—Slight.
11	15.10	—0.37	118,715	180,985	20.2	30.3	29.7	5,890	+ 447	3.382	401,527	VI—Strong.
12	14.75	—0.35	116,740	181,081	19.8	30.4	29.7	5,889	+ 96	3.351	391,134	VI—Strong.
13	14.60	—0.15	115,180	180,400	19.6	30.2	29.7	5,887	— 681	3.295	379,715	XI—Slight.
15	14.10	—0.50	112,140	180,299	19.1	30.2	29.0	5,883	— 101	3.296	369,886	VI—Slight.
16	13.85	—0.25	109,695	179,322	18.7	30.0	28.0	5,880	— 977	3.290	361,620	V—Slight.
17	13.65	—0.20	107,790	178,596	18.4	29.9	27.8	5,880	— 724	3.276	353,167	XII—Slight.
18	14.15	+0.50	108,780	176,648	18.5	29.6	28.0	5,883	—2,150	3.329	362,076	VI—Moderate.
19	14.93	+0.78	113,230	176,510	19.2	29.6	28.8	5,892	— 138	3.364	380,901	VI—Mild.
20	15.65	+0.72	117,096	176,137	19.9	29.5	29.7	5,899	— 373	3.421	401,596	VII—Slight.
22	16.58	+0.93	121,735	175,256	20.6	29.4	31.0	5,905	— 851	3.502	426,389	III—Slight.
23	16.97	+0.42	124,975	176,221	21.2	29.5	31.0	5,908	+ 935	3.512	438,590	III—Slight.
24	17.55	+0.58	128,420	176,238	21.8	29.5	32.0	5,912	+ 17	3.587	460,685	IX—Slight.
25	18.33	+0.78	132,675	175,892	22.4	29.5	33.2	5,919	— 356	3.654	484,839	XI—Slight.
26	18.60	+0.27	136,620	178,229	22.1	29.9	34.0	5,924	+2,347	3.674	501,817	XII—Slight.
27	18.35	—0.25	135,125	178,214	22.8	29.9	33.5	5,921	— 15	3.644	492,328	X—Moderate.
29	16.00	—2.35	122,660	179,631	20.8	30.1	31.5	5,899	+1,417	3.447	422,967	VII—Mild.
30	14.75	—1.25	115,430	179,769	19.6	30.1	29.0	5,890	+ 138	3.363	388,279	XII—Mild.
May 1	13.70	—1.05	108,750	179,263	18.5	30.0	27.8	5,880	— 506	3.291	357,981	XII—Mild.
2	12.70	—1.00	102,420	178,824	17.4	29.9	26.8	5,876	— 439	3.257	333,734	XII—Mild.

* From reduction at office of first district engineer.

† Where a day is omitted the rise or fall given on the following day is for 48 hours.

Results of discharge observations, Mississippi River, below New Madrid, Missouri.

Date.	New Madrid gauge.		Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations.	No. of soundings.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.						
			Water.	Below datum.	Mean.	Mean datum.	Maximum.							
1890.	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*			
Mar. 25	36.6	0.0	239,698	178,472	39.5	28.8	51.8	6,066	.....	5.546	1,329,387	XI—Slight....	12	37
Apr. 8	37.7	—0.2	246,492	172,984	40.3	28.8	52.0	6,114	— 488	.....	.....	VI—Brisk	.....	48
9	37.3	—0.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	36.9	—0.4	240,893	172,525	39.5	28.7	53.0	6,106	— 459	5.290	1,274,319	X—Brisk	22	65
11	36.2	—0.7	236,028	171,558	38.7	28.5	52.5	6,091	— 967	5.231	1,234,597	VI—Brisk	23	67
12	35.6	—0.6	233,081	172,879	38.3	28.7	53.0	6,065	+1,321	5.209	1,214,031	VII—Brisk ...	23	65
13	34.9	—0.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
14	34.2	—0.7	226,213	174,597	37.3	29.0	52.0	6,058	+1,718	4.746	1,073,506	XII—Brisk ...	23	32

Discharge measurements were at high-water section of 1888–'89; datum line taken at same elevation as in that series.

Price meter No. 10, used at six-tenths depth from the surface for mean velocity at each velocity station; meter was rated April 11, 1890, and the resulting value of the constants, $a = 3.9897$, $b = +0.2986$, were used in computing discharges.

E. L. Harman, assistant engineer, chief of party.

EXTRACTS FROM REPORT OF MR. WILLIAM GERIG, ASSISTANT ENGINEER, UPON OFFICE REDUCTION OF DISCHARGE OBSERVATIONS, MISSISSIPPI RIVER, AT HELENA, ARKANSAS, 1888-'89.

MEMPHIS, TENN., *February* 20, 1890.

* * * * * * *

The co-efficients to be used in reducing the registrations of the meter to velocity in feet per second, were determined by causing the meter to move through still water, over a known distance, at various velocities, the time and number of registrations being noted.

* * * * * * *

The observations* were reduced by the method of least squares. * * * In the final reduction the widths were calculated and the soundings plotted on cross-section sheets, as were also the velocities. The total area was divided into partial areas and these were calculated by counting the squares, and were multiplied by the mean velocities of the partial areas which were taken from the cross-section sheets. The product was the partial discharge, and the sum of the partial discharges gave the total discharge, and this divided by the total area gave the mean velocity. The counting of the registrations was done in the field and checked. The results of computation were copied in a tabular form accompanying this report and also into the note-books. The gauge-readings correspond to the mean time of observation. The gauge was read at the beginning and ending of the day's work. The rise or fall for twenty-four hours is the difference in the mean gauge-reading for that day and the preceding one.

The computation of datum areas has been made in the following manner: The datum was assumed to correspond to the gauge-reading of 32.32 feet; the datum width was taken as 4,818 feet, that being the measured width and gauge-reading on March 2, 1889. The slope of the banks down to 21 feet on gauge was uniform, also from 21 to 19 feet, from 19 to 13 feet, and below 13 feet, and the datum areas have been computed by the formula:

$$\text{Datum area} = (32.32 - h)\,\frac{4818 + w}{2} + \text{water area},$$

where h = gauge and w = width.

The formula between 21 and 19 feet on gauge becomes:

$$\text{Datum area} = (32.32 - 21)\,\frac{4818 + 4700}{2} + (21 - h)\,\frac{4700 + w}{2} + \text{water area}$$

$$= 53872 + (21 - h)\,\frac{4700 + w}{2} + \text{water area},$$

in which 4,700 feet is the width for 21-foot stage.

For stages between 19 and 13 feet:

$$\text{Datum area} = 53872 + (21 - 19)\,\frac{4700 + 3392}{2} + (19 - h)\,\frac{3392 + w}{2} + \text{water area}$$

$$= 61964 + (19 - h)\,\frac{3392 + w}{2} + \text{water area},$$

in which 3,392 feet is the width at 19-foot stage.

For stages below 13 feet the formula becomes:

$$\text{Datum area} = 61964 + (19 - 13)\,\frac{3392 + 2705}{2} + (13 - h)\,\frac{2705 + w}{2} + \text{water area}$$

$$= 80255 + (13 - h)\,\frac{2705 + w}{2} + \text{water area},$$

in which 2,705 feet is the width at 13-foot stage.

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* For date of observations, etc., see Mr. Sturtevant's report herewith.

The mean depth has been obtained by dividing the water area by the width, and the mean datum depth has been obtained by dividing the datum area by the datum width. Maximum depth was taken directly from the notes. Scour or fill has been obtained by taking the difference of the datum areas, scour indicated by the positive sign. The direction of the wind is indicated by dividing the horizon into twelve parts and numbering the parts the same as the hours on a clock dial, XII being up-stream and indicating a down-stream wind.

The entire work has been checked in various ways and great care has been taken to eliminate all errors of computation.

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Capt. SMITH S. LEACH,
Corps of Engineers, U. S. A.,
Memphis, Tenn.

Results of discharge observations, Mississippi River, Helena, Arkansas, 1888–1889.*

[Method.—Meter.]

Date.	Gauge.		Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.				
			Water.	Below datum.	Mean.	Mean datum.	Maximum.					
1888.	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*	
Nov. 28	26.70	−0.50	133,997	160,832	28.3	33.2	75.0	4,732	.....	4.219	565,310	XII—Light.
29*	25.98	−0.72	129,545	159,796	27.4	33.2	72.0	4,725	− 1,036	4.390	568,714	VIII—Very light.
30	24.95	−1.03	125,124	160,278	26.5	33.2	74.4	4,722	+ 482	4.383	548,408	X—Moderate.
Dec. 1	23.81	−1.14	118,436	158,999	25.1	33.0	72.0	4,715	− 1,279	5.381	518,854	XI—Moderate.
2	22.40	−1.41										
3	21.12	−1.28	107,901	161,213	22.9	33.5	73.0	4,702	+ 2,214	4.570	493,081	VIII—Moderate.
4	19.87	−1.25	98,462	156,970	28.1	32.6	74.0	3,505	− 4,243	4.641	456,952	IV—Very light.
5	18.57	−1.30	92,620	156,011	28.5	32.5	71.0	3,244	− 959	4.773	442,074	VI—Light.
6	17.29	−1.28	88,600	156,106	28.6	32.5	67.0	3,090	+ 95	4.719	418,138	XII—Moderate.
7	15.99	−1.30	83,572	155,000	28.5	32.2	68.0	2,938	− 1,106	4.402	367,930	IV—Moderate.
8	14.74	−1.25	81,521	156,859	28.3	32.6	68.5	2,887	+ 1,859	4.097	333,977	IV—Moderate.
9	13.60	−1.14										
10	12.70	−0.90	69,929	150,992	26.1	31.3	61.0	2,680	− 5,867	4.068	284,144	XII—Light.
11	11.82	−0.88	67,645	151,071	25.3	31.4	64.0	2,670	+ 79	3.927	265,627	I—Very light.
12	11.06	−0.76	67,315	152,780	25.2	31.7	61.2	2,666	+ 1,709	4.057	273,108	II—Very light.
13	10.50	−0.56	65,424	152,267	25.5	31.6	62.3	2,565	− 513	4.101	268,752	VII—Moderate.
14	9.97	−0.53	64,097	152,245	25.6	31.6	62.5	2,505	− 22	3.949	253,139	XII—Very light.
15	9.50	0.47										IV—Strong.
16	9.42	−0.08	61,910	151,482	24.8	31.4	60.2	2,500	− 763	3.931	243,358	VII—Light.
17	9.35	−0.07	62,485	152,239	25.0	31.6	62.3	2,500	+ 757	3.931	245,623	IX—Light.
18	9.24	−0.11	62,567	152,607	25.0	31.7	61.0	2,500	+ 368	3.830	239,577	IX—Light.
19	9.06	−0.17	61,395	151,884	24.7	31.5	60.0	2,490	− 723	3.908	239,947	XI—Light.
20	8.99	−0.08	61,990	152,631	25.0	31.7	60.0	2,475	+ 747	3.893	241,337	VI—Light.
21	8.93	−0.06	60,440	151,231	24.5	31.4	60.0	2,473	− 1,400	3.915	236,656	
22	8.95	+0.02	60,155	150,889	24.4	31.3	60.0	2,470	− 342	3.824	229,064	I—Very light.
23	9.25	+0.30										
24	9.62	+0.37	61,450	150,401	24.6	31.2	56.0	2,500	− 488	3.928	241,347	IV—Light.
25	10.25	+0.63	63,730	151,204	24.9	31.4	58.2	2,555	+ 803	3.954	251,951	IV—Very light.
26	10.96	+0.71	64,828	150,442	25.3	31.2	59.0	2,562	− 762	4.209	272,842	IX—Very strong.
27	11.44	+0.47	66,284	150,693	25.3	31.3	59.0	2,620	+ 251	4.130	273,787	IX—Moderate.
28	11.69	+0.25	67,913	151,682	25.4	31.4	60.0	2,686	+ 989	4.133	280,641	XII—Moderate.
29	11.95	+0.26	69,955	153,024	26.1	31.8	60.0	2,680	+ 1,342	4.120	288,827	XII—Light.
30	12.45	+0.50										
31	13.10	+0.65	71,752	151,702	26.5	31.4	61.0	2,705	− 1,322	4.143	297,185	XII—Light.

1889.												
Jan. 1	13.92	+0.82	75,125	152,779	27.0	31.7	3.0	2,785	+ 1,077	4.239	317,972	XII—Moderate.
2	14.85	+0.23										
3	15.34	+0.49	80,594	154,035	28.0	31.9	63.7	2,888	+ 1,256	4.240	341,753	II—Light.
4	15.62	+0.28										
5	15.60	−0.02	79,631	152,340	27.1	31.6	64.0	2,938	− 1,695	4.354	316,784	XI—Light.
6	15.25	−0.35										
7	14.86	−0.39	77,349	152,307	26.5	31.6	63.5	2,888	− 33	4.227	326,359	VI—Light.
8	14.48	−0.38	76,572	152,670	26.7	31.7	63.2	2,862	+ 368	4.172	319,416	Fog.
9	14.49	−0.01	77,331	153,398	27.0	31.8	63.7	2,862	+ 728	4.292	331,911	VIII—Strong.
10	14.74	+0.25	77,153	152,446	26.9	31.6	63.0	2,873	− 952	4.234	326,684	VII—Very light.
11	15.39	+0.65	80,059	153,379	27.5	31.8	62.8	2,908	+ 933	4.472	358,086	Calm.
12	16.40	+1.01	84,127	154,430	28.2	32.0	65.3	2,989	+ 1,051	4.483	377,117	IV—Light.
13	18.00	+1.60										
14	19.65	+1.65	94,574	153,909	27.9	31.9	67.0	3,394	− 521	4.778	450,361	XII—Light.
15	21.95	+2.30					71.2					IV—Moderate.
16	24.32	+2.37	127,275	165,322	27.1	34.4	75.0	4,700	+11,414	4.741	603,411	VII—Moderate.
17	25.56	+1.23	131,624	163,876	27.8	34.0	78.0	4,724	− 1,447	4.781	629,580	XII—Moderate.
18	26.36	+0.80	133,914	162,355	28.1	33.7	78.0	4,734	− 1,521	4.630	619,969	
19	27.03	+0.66	137,962	163,248	29.1	33.9	78.5	4,742	+ 893	4.635	639,500	II—Light.
20	27.98	+0.95										
21	28.65	+0.67	141,163	158,726	29.6	33.0	77.5	4,766	− 4,522	4.650	656,457	Calm.
22	29.50	+0.85	145,823	159,028	30.5	33.1	79.0	4,777	+ +302	4.700	685,324	VI—Light.
23	30.40	+0.89	151,100	160,313	31.6	33.2	80.0	4,779	+ 1,285	5.016	757,926	I—Light.
24	31.15	+0.75	161,333	166,931	33.7	34.7	80.0	4,792	+ 6,618	4.797	773,807	II—Light.
25	31.35	+0.20										I—Fog.
26	31.25	−0.10										Fog.
27	30.85	−0.40	149,397	156,383	31.2	32.5	79.5	4,787	−10,548	4.658	695,785	VIII—Strong.
28	30.10	−0.75	150,039	160,687	31.4	33.3	79.5	4,775	+ 4,304	4.696	704,632	X—Very strong.
29	29.14	−0.96	142,318	157,556	29.9	32.7	79.5	4,766	− 3,131	4.697	668,887	IX—Light.
30	28.06	−1.08	134,860	155,250	28.4	32.3	77.0	4,755	− 2,306	4.596	619,811	V—Moderate.
31	27.25	−0.80	132,382	156,595	27.9	32.6	75.0	4,743	+ 1,345	4.553	602,791	I—Very light.
Feb. 1	26.86	−0.39	131,322	157,407	27.7	32.7	75.0	4,737	+ 312	4.503	591,403	I—Very light.
2	26.88	+0.02	133,727	159,701	28.2	33.2	77.0	4,740	+ 2,294	4.468	597,532	VII—Moderate.
3	27.25	+0.37										
4	27.79	+0.54	136,612	158,273	28.7	32.7	76.0	4,756	− 1,428	4.709	643,403	VI—Light.
5	28.44	+0.64	139,858	158,445	29.4	32.8	75.2	4,763	+ 172	4.581	640,760	X—Strong.
6	29.01	+0.57	140,845	156,699	29.5	32.6	75.5	4,776	− 1,746	4.674	657,797	XII—Strong.
7	29.33	+0.31	142,372	156,717	29.8	32.6	77.0	4,777	+ 18	4.713	671,028	VI—Moderate.
8	29.28	−0.05	144,432	159,029	30.2	33.1	77.2	4,780	− 2,312	4.750	684,051	VII—Light.
9	28.95	−0.33	142,580	158,749	29.8	32.9	76.0	4,778	− 280	4.600	655,905	XI—Light.
10	28.08	+0.87										
11	27.03	−1.05	134,209	159,567	28.2	33.2	76.0	4,769	+ 818	4.414	592,456	IX—Moderate.
12	25.62	−1.41	128,352	160,331	27.6	33.3	75.0	4,728	+ 764	4.334	556,252	IX—Light.
13	23.90	−1.72	116,969	157,698	24.8	32.6	75.0	4,714	− 3,238	4.417	516,585	VII—Strong.
14	22.06	−1.83										Heavy fog.
15	20.13	−1.93										Heavy fog.
16	18.60	−1.53	89,396	152,699	27.1	31.7	67.0	3,293	− 4,399	4.354	389,193	VI—Moderate.

* From reduction at office of second district engineer.

Results of discharge observations, Mississippi River, Helena, Arkansas, 1888–1889*—Continued.

[METHOD.—Meter.]

Date.	Gauge.		Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.				
			Water.	Below datum.	Mean.	Mean datum.	Maximum.					
1889.	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*	
Feb. 17	17.18	—1.42										
18	16.19	—0.99	83,028	154,042	27.1	32.0	65.0	3,061	+ 1,343	4.261	353,797	XI—Strong.
19	15.18	—1.01	80,428	154,554	26.9	32.0	64.0	2,984	+ 512	4.205	338,195	XI—Moderate.
20	14.51	—0.67	76,823	152,859	26.6	31.7	62.3	2,883	— 1,695	4.187	321,689	IV—Light.
21	14.69	+0.17	77,802	153,289	27.0	31.8	64.0	2,883	+ 430	4.391	341,645	V—Very light.
22	16.60	+1.91	83,215	152,921	27.1	31.7	66.0	3,073	— 368	4.601	382,856	VII—Light.
23	20.54	+3.94	†100,408	156,236	25.8	32.5	70.5	3,897	+ 3,315	†4.951	†497,161	XII—Strong.
24	23.85	+3.31										
25	25.96	+2.11	129,085	159,427	27.3	33.2	74.2	4,731	+ 3,191	4.730	610,507	XI—Moderate.
26	27.93	+1.96	140,113	161,130	29.4	33.4	75.6	4,757	+ 1,703	4.795	671,320	VI—Very light.
27	29.54	+1.61	147,967	161,308	30.9	33.5	77.0	4,780	+ 178	4.892	723,872	VI—Light.
28	30.95	+1.41	155,742	162,332	32.4	33.7	79.5	4,802	+ 1,024	4.856	756,200	Fog.
Mar. 1	31.72	+0.77					79.0	4,809				Fog.
2	32.32	+0.60	164,099	164,099	34.1	34.1	81.2	4,818	+ 1,767	4.873	799,657	XII—Moderate.
3	32.30	—0.02										
4	32.09	—0.21	163,218	164,301	33.9	34.2	80.5	4,810	+ 202	4.569	745,773	XII—Very light.
5	31.65	—0.44	160,826	164,049	33.5	34.1	80.0	4,804	— 252	4.606	740,737	XI—Moderate.
6	31.14	—0.51	154,837	165,511	32.3	33.3	78.0	4,800	— 3,538	4.562	706,082	VIII—Light.
7	30.75	—0.39	154,370	161,912	32.2	33.6	78.0	4,790	+ 1,401	4.583	707,517	XI—Light.
8	30.41	—0.34	151,528	160,690	31.7	33.3	78.0	4,785	— 1,213	4.474	677,952	X—Moderate.
9	30.26	—0.15	150,585	160,475	31.5	33.3	78.0	4,784	— 224	4.452	670,488	XI—Strong.
10	29.93	—0.33										
11	29.46	—0.47	144,604	158,304	30.3	32.9	76.3	4,779	— 2,171	4.388	634,518	VI—Very light.
12	28.75	—0.71	141,278	158,382	29.7	32.9	75.5	4,764	+ 78	4.392	620,471	VI—Very light.
13	27.94	—0.81	137,461	158,424	28.8	32.9	75.0	4,754	+ 42	4.377	601,689	I—Light.
14	27.02	—0.92	132,030	157,388	27.8	32.7	75.0	4,751	— 1,036	4.430	584,788	V—Very light.
15	26.12	—0.89	127,405	156,995	26.9	32.6	73.5	4,735	— 393	4.363	555,891	
16	25.52	—0.60	124,891	157,351	26.4	32.7	72.0	4,729	+ 356	4.343	542,347	IX—Light.
17	24.83	—0.69										
18	24.43	—0.40	118,029	155,568	25.0	32.2	72.0	4,723	— 1,783	4.428	522,693	VI—Light.
19	24.05	—0.38	117,766	157,210	25.0	32.7	71.0	4,721	+ 1,642	4.355	512,825	XII—Strong.
20	23.55	—0.50	114,676	156,482	24.3	32.6	70.5	4,716	— 728	4.403	504,617	XII—Light.
21	22.90	—0.65	111,118	156,909	23.6	32.5	72.0	4,713	— 473	4.271	474,499	I—Light.
22	22.30	—0.60	108,466	156,211	23.0	32.5	69.5	4,712	+ 202	4.239	459,830	II—Moderate.
23	21.81	—0.49	105,845	155,884	22.5	32.4	68.0	4,708	— 327	4.342	459,589	III—Light.

	24	21.50	−0.31										
	25	21.79	+0.29	105,570	155,701	22.4	32.4	68.5	4,708	− 182	4.414	466,027	XII—Light.
	26	22.60	+0.80	112,434	158,749	23.0	32.9	70.5	4,714	+3,048	4.440	498,114	XI—Very light.
	27	23.79	+1.19	117,662	158,346	24.0	32.7	71.0	4,721	− 403	4.402	517,228	X—Light.
	28	24.83	+1.04	122,082	158,798	24.0	32.9	72.0	4,731	+ 447	4.449	547,395	XII—Light.
	29†	25.42	+0.59										V—Moderate.
	30†	25.45	+0.03										
	31‡	25.28	−0.17										
Apr.	1	25.23	−0.05	125,975	159,506	26.5	33.2	74.0	4,732	+ 713	4.419	556,337	XI—Moderate.
	2	25.02	−0.21										
	3	24.51	−0.51	120,980	158,180	25.6	32.7	71.8	4,721	−1,336	4.264	516,094	X—Light.
	4	24.02	−0.49										
	5	23.35	−0.67	115,946	158,692	24.6	32.9	72.3	4,713	+ 512	4.344	563,592	XI—Very light.
	6	22.69	−0.65	114,109	159,961	24.2	33.3	72.0	4,711	+1,269	4.285	488,943	XII—Strong.
	7	22.23	−0.46										
	8	21.95	−0.28	110,423	159,815	23.5	33.2	72.0	4,708	− 146	4.289	468,049	X—Very light.
	9	21.90	−0.05	110,777	160,402	23.5	33.3	72.5	4,707	+ 587	4.338	490,477	VI—Light.
	10	21.82	−0.08	111,022	161,028	23.6	33.4	73.0	4,707	+ 626	4.317	479,300	VIII—Very light.
	11	21.65	−0.17	110,622	161,488	23.5	33.5	73.5	4,707	+ 410	4.278	472,722	VII—Light.
	12	21.20	−0.45										Very strong.
	13	20.84	−0.36	101,798	156,358	26.3	33.6	72.5	3,895	−5,080	4.347	442,536	XI—Moderate.
	14	20.23	−0.61										
	15	19.79	−0.44	98,330	157,240	28.2	32.7	70.0	3,495	+ 882	4.319	424,637	XII—Light.
	16	19.48	−0.31	95,727	155,729	28.2	32.4	69.1	3,393	−1,511	4.352	416,484	I—Very light.
	17	19.16	−0.32	94,389	155,695	27.9	32.4	70.0	3,392	− 44	4.445	419,562	VII—Very light.
	18	18.82	−0.34	92,040	154,508	27.5	32.0	69.0	3,341	−1,092	4.311	396,770	VI—Strong.
	19	18.49	−0.33	88,937	152,605	27.0	31.7	67.5	3,291	−1,988	4.442	395,048	VI—Strong.
	20	18.40	−0.09	88,657	152,626	26.9	31.7	66.7	3,291	+ 21	4.346	385,319	X—Very light.
	21	18.80	+0.40										
	22	19.45	+0.65	94,082	154,226	27.7	32.0	70.0	3,393	+1,600	4.486	423,969	I—Moderate.
	23	20.23	+0.78	96,714	153,818	26.2	31.9	70.3	3,694	− 408	4.413	426,760	XI—Very light.
	24	20.85	+0.62	102,239	156,317	21.7	32.6	69.8	4,708	+2,999	4.445	454,408	XII—Light.
	25	21.40	+0.55	105,466	157,478	22.4	32.8	71.0	4,708	+ 661	4.404	464,437	XII—Light.
	26	21.91	+0.51	108,068	157,648	22.9	32.8	69.2	4,712	+ 170	4.401	475,572	XI—Very light.
	27	22.67	+0.76	110,920	156,888	23.6	32.6	70.0	4.714	− 760	4.478	496,670	X—Moderate.
	28	23.35	+0.68										
	29	23.57	+0.22	114,358	156,065	24.3	32.5	71.0	4,715	− 828	4.455	509,474	X—Light.
	30	23.23	−0.35	113,752	157,122	24.1	32.7	70.2	4,714	+1,057	4.410	501,645	XI—Moderate.
May	1	22.27	−0.95	109,808	157,676	23.3	32.8	70.0	4,708	+ 554	4.267	468,497	X—Moderate.
	2	20.84	−1.43	102,363	156,987	21.9	32.7	68.5	4,702	− 689	4.273	437,446	XI—Moderate.

* From reduction at office of second district engineer.
† For February 23 the note-book gives these additional results for the chute: area, 4,002; mean velocity, 1,497; discharge, 5,991.
‡ Launch pump broken.

Results of discharge observations, Mississippi River, Arkansas City, Arkansas, 1887:

METHOD.—Meter at six-tenths depth from surface.

Date.	Gauge.		Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Remarks.	No. of velocity stations.	No. of soundings.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.						
			Water.	Below datum.	Mean.	Mean datum.	Maximum.							
1887.	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*			
Mar. 22	46.59	+0.05	233,105	215,475	68.0	63.5	95.0	3,414	.....	6.122	1,427,177	.....	16	32
23	46.60	+0.05	233,667	216,003	68.1	63.6	97.0	3,414	+ 528	6.197	1,447,969	.....	16	40
24	46.61	0.00	247,404	229,701	72.1	67.7	97.0	3,416	+13,698	5.982	1,479,975	.....	16	42
25	46.63	+0.05	*240,852	.....	70.1	.....	.....	3,420	.....	5.839	1,406,309	.....	16†	.....
26	46.63	0.00	234,299	216,518	68.2	63.8	96.0	3,420	—13,183	6.079	1,424,320	a. m.	16	69
										6.024	1,411,396	p. m.	16	69

* Interpolated.

The widths tabulated were scaled from the plotted cross-sections, and were measured from bank to bank. There was a discharge beyond the banks which increased the water width by 330 feet, and the water area by 1,084 square feet; this overflow amounted to 1,666 cubic feet per second the first two days, and subsequently to 1,626 cubic feet per second. The areas and discharges given above include these quantities. The datum line was taken at 41.73 feet on the gauge, as in the series of 1884–'85, and datum width at 3,89 5 feet. For the meter rating see page 3151.

MEMORANDA TO ACCOMPANY TABULATED RESULTS OF FINAL REDUCTION IN SECRETARY'S OFFICE, MISSISSIPPI RIVER COMMISSION, OF DISCHARGE OBSERVATIONS MADE ON THE MISSISSIPPI RIVER AT ARKANSAS CITY, ARKANSAS, 1889.

OCTOBER 25, 1889.

The notes of these observations were received from the third district in May, 1889, for recomputation.

A map of the locality drawn to a scale of 1:7200 accompanied the notes. This map shows the discharge section at apparently the same place as it was in 1884–'85, and also shows the arrangement of fixed signals on shore by which the sounding and velocity stations were located. The sounding stations were at intervals of 75 feet across the river, every fourth one being also a velocity station. The water's edge at each bank was located by measuring from the section hub on that bank; this also determined the river width for that day.

All the velocities of this series were measured with the W. G. Price current meter, No. 5; for a description of the Price meter and outfit, see Report Chief of Engineers, 1887, page 2821. The chronograph slips did not accompany the notes; the registrations, however, had been counted in the field and recorded in the notes and the results were adopted in this computation. The observer states that on February 22 and 23, no paper being on hand, the revolutions of the meter wheel were found by watching the registering points.

Three sets of rating observations were made with this meter at Arkansas City during the season; the results of reduction in this office by the usual method are given in the following table:

Date of observations.	No. of observations.	a	b	Mean error of observations.	Mean error of a	Mean error of b	Remarks.
Dec. 4, 1888...	12	3.7989	+0.1943	±0.280	±0.121	±0.215	In running water.
Feb. 27, 1889..	15	3.9921	+0.0187	±0.188	±0.109	±0.165	Do.
Mar. 27, 1890 .	22	3.8421	+0.0785	±0.238	±0.075	±0.145	Do.

These results were combined by weighting a and b inversely as the squares of the mean errors of a and b in each series; the resulting equation, $y = 3.8712\,x + 0.0816$, was used in computing all of the 1889 series of discharges at this station.

(In 1884–'85 six sets of rating observations were made with this meter; the results are published in Report Chief of Engineers, 1887, page 2815. Also a set of rating observations was made with this meter near Wilson's Point, La., July 4, 1889; the results are published herewith.)

The computations of areas of cross-section were made and checked in the manner described at length in Report Chief of Engineers, 1887, pages 2823–2826. There were no lead-line corrections and the soundings were taken directly from the note-books.

The discharges were found by the method described in the report accompanying the final reduction in Secretary's office of the Carrollton observations of 1883. In the present series, however, the meter was usually run at six-tenths the depth from the surface, and for 150 seconds.

The datum areas were computed in the following manner: Datum was assumed at 41.73 feet on the gauge; this was the elevation of datum in 1884–'85 and was adopted in this work in order to conveniently make comparisons between the different series. Datum width was taken as 3,395 feet. The width at 35.25 feet on the gauge was taken as observed, as 3,373 feet; at 29 feet, as 3,363 feet, before February 15; after that date as 3,352 feet; at 22.67 feet, as 3,321 feet. The following formulas were used in computing the datum areas, in which h represents gauge-reading and w observed width.

Between 29 and 35.25 feet on the gauge:

$$\text{Datum area} = (41.73 - 35.25)\frac{3395 + 3373}{2} + (35.25 - h)\frac{3373 + w}{2} + \text{water area}$$

$$= 21928 + (35.25 - h)\frac{3373 + w}{2} + \text{water area.}$$

Between 22.67 and 29 feet on the gauge:

$$\text{Datum area} = 21928 + (35.25 - 29)\frac{3373 + {}^{*}3352}{2} + (29 - h)\frac{{}^{*}3352 + w}{2} + \text{water area}$$

$$= 42944 + (29 - h)\frac{{}^{*}3352 + w}{2} + \text{water area.}$$

* 3363 was used prior to February 15, 1889.

Below 22.67 on the gauge:

$$\text{Datum area} = 42944 + (29 - 22.67)\frac{*3352 + 3321}{2} + (22.67 - h) \times \frac{3321 + w}{2} + \text{water area}$$

$$= 64064 + (22.67 - h)\frac{3321 + w}{2} + \text{water area.}$$

The gauge used was the standard gauge at the elevator. The gauge inspectors' level notes of September 7, 1887, and October 4, 1889, show that this gauge was 0.2 foot too high, and all the records between those dates have been corrected by adding 0.2 foot to each reading. The zero of this gauge is 116.44 feet above the Cairo datum plane, survey Mississippi River.

The gauge-readings given for days on which the discharge section was sounded correspond to mean time of observations; for other days the mean daily reading is given. The rise or fall in preceding twenty-four hours is derived from the regular record.

The maximum depths have been taken directly from the soundings.

The direction and force of wind have been copied from the notes; the direction is indicated by the figures of a clock dial, XII o'clock being up-stream and denoting a down-stream wind, VI denoting an up-stream wind, etc.

The figures following the direction evidently indicate the velocity in miles per hour as they agree with Trautwine's wind-table which had been copied into one of the note-books.

The mean velocities, mean depths, mean datum depths, and scour and fill have been computed in the usual manner.

Accompanying the tables are two plates. On one is the map of the locality, and on the other the discharges, areas, and mean velocities as abscissas have been plotted to gauge heights, and the datum areas and gauge record plotted to time abscissas. On the latter plate are also plotted two profiles of the discharge cross-section.

Results of other discharge observations at this station are published as follows: October 6, 1884, to April 9, 1885, gauge-reading from 7.42 feet to 41.73 feet; report Mississippi River Commission, 1887, pages 2838–2840.

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* 3363 was used prior to February 15, 1889.

Results of discharge observations, Mississippi River, at Arkansas City, Arkansas, 1889.

METHOD.—Meter at six-tenths depth from the surface.

Date.	Gauge.		Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations.	No. of soundings.
	Reading.	Rise or Fall in the preceding 24 hours.	Area.		Depth.			Width.						
			Water.	Below datum.	Mean.	Mean datum.	Maximum.							
1889.	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*			
Jan. 22	33.45	+0.80	188,640	211,638	54.5	62.3	81.0	3,371	.....	4.298	789,225	.....	11	44
23	34.10	+0.75	185,978	211,784	55.2	62.4	83.0	3,371	+ 146	4.805	893,714	.....	11	44
24	34.68	+0.65	190,945	214,795	56.6	63.3	83.0	3,372	+ 3,011	4.444	848,585	.....	9	45
25	35.20	+0.45	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
26	35.45	+0.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
27	35.50	+0.05	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
28	35.25	−0.25	191,391	213,319	56.7	63.8	85.0	3,373	− 1,476	4.707	900,919	VIII—30	11	45
29	35.05	−0.30	192,706	215,309	57.1	63.4	85.0	3,373	+ 1,990	4.326	833,659	VIII—10	11	45
30	34.55	−0.40	191,040	215,329	56.7	63.4	85.5	3,372	+ 20	4.421	844,502	II—5	11	46
31	34.10	−0.45	189,542	215,348	56.2	63.4	86.0	3,372	+ 19	4.302	815,354	XI—15	11	46
Feb. 1	33.65	−0.45	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	33.52	−0.20	187,332	215,094	55.6	63.4	84.5	3,371	− 254	4.542	850,838	II—3	11	46
3	33.30	−0.15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	33.30	0.00	185,374	213,877	55.0	63.0	85.5	3,371	− 1,217	4.288	794,911	.....	11	45
5	33.35	+0.05	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	33.50	+0.20	179,841	207,671	53.3	61.2	83.0	3,372	− 6,206	4.412	793,375	.....	11	45
7	33.76	+0.30	178,559	205,512	53.0	60.5	81.5	3,372	− 2,159	4.375	781,219	IV—15	11	45
8	33.86	+0.05	179,757	206,373	53.3	60.8	83.0	3,372	+ 861	4.106	738,416	IV—15	11	45
9	33.80	−0.10	181,426	208,243	53 8	61.8	83.0	3,371	+ 1,870	4.261	773,052	XI—20	11	45
10	33.55	−0.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	33.07	−0.55	175,670	204,949	52.1	60.4	82.0	3,371	− 3,294	4.106	721,228	VII—5	11	45
12	32.25	−0.80	175,206	207,248	52.0	61.9	81.5	3,370	+ 2,299	4.111	720,280	VII—5	11	45
13	31.10	−1.10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
14	29.95	−1.30	167,948	207,740	49.9	61.2	78.0	3,368	+ 492	3.722	625,057	III—10	11	45
15	28.23	−1.40	160,195	205,761	47.7	60.6	78.5	3,360	− 1,979	.....	.....	III—5	.....	44
16	26.85	−1.35	142,706	192,845	42.7	56.8	68.5	3,341	−12,916	3.576	510,287	VI—3	44	44
17	25.40	−1.65	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
18	24.10	−1.45	133,014	192,319	40.0	56.6	67.5	3,326	− 526	.....	.....	IX—20	.....	44
19	22.67	−1.35	128,954	193,018	38.8	56.9	63.0	3,321	+ 699	3.225	415,822	XII—12½	11	44
20	21.53	−1.15	125,317	193,153	38.0	56.9	66.0	3,296	+ 135	3.240	406,072	II—10	11	44
21	20.61	−0.90	125,167	196,035	38.1	57.7	65.0	3,285	+ 2,882	3.232	404,531	XII—3	11	43
22	20.20	−0.35	123,943	196,164	37.7	57.8	65.5	3,284	+ 129	3.214	398,403	III—3	11	44
23	21.02	+1.00	127,570	197,084	38.8	58.1	66.0	3,285	+ 920	4.406	434,361	XII—20	11	44
24	23.50	+2.30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Results of discharge observations, Mississippi River, at Arkansas City, Arkansas, 1889—Continued.

METHOD.—Meter at six-tenths depth from the surface.

Date.	Gauge.		Cross-section of discharge.						Sconr or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations.	No. of soundings.
			Area.		Depth.			Width.						
	Reading.	Rise or fall in the preceding 24 hours.	Water.	Below datum.	Mean.	Mean datum.	Maximum.							
1889.	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*			
Feb. 25	25.53	+2.30	143,482	198,012	43.1	58.3	69.0	3,327	+ 928	3.708	531,990	X—5	11	44
26	27.59	+1.95	148,096	195,762	44.3	57.7	73.5	3,346	— 2,250	3.962	586,734	II—5	11	44
27	29.25	+1.70	156,287	198,393	46.6	58.4	73.5	3,353	+ 2,631	3.889	607,756	II—2	11	44
28	30.67	+1.35	160,090	197,434	47.7	58.2	74.0	3,359	— 959	3.967	635,103	II—2	11	44
Mar. 1	32.00	+1.20										Calm		
2	32.83	+0.85	168,314	198,403	49.9	58.4	77.5	3,372	+ 969	4.150	698,573		11	44
3	33.55	+0.70												
4	33.76	+0.30	167,612	194,568	49.6	57.3	78.0	3,376	—3,835	4.409	738,923	IX—5	11	44
5	34.08	+0.25	168,417	194,293	49.9	57.2	77.5	3,376	— 275	4.214	709,707	IX—15	11	44
6	34.53	+0.50	172,071	196,429	51.0	57.9	78.5	3,376	+2,136	4.345	747,641	V—10	13	44
7	31.86	+0.25	172,764	196,008	51.2	57.7	78.5	3,376	— 421	4.340	849,723	IX—12½	13	45
8	35.00	+0.15	172,162	194,934	51.0	57.4	78.0	3,377	—1,074	4.330	745,442	XI—10	13	45
9	34.96	0.00	173,814	196,721	51.5	57.9	78.0	3,377	+1,787	4.187	727,761	VIII—8	11	45
10	34.85	—0.15												
11	34.63	—0.20	174,967	198,987	51.8	58.6	79.0	3,377	+2,266	4.176	730,743	XII—2	11	45
12	34.18	—0.50	174,508	200,047	51.7	58.9	81.0	3,376	+1,060	4.121	719,228	XI—2	12	44
13	33.61	—0.55	171,469	198,930	50.8	58.6	77.0	3,375	—1,117	4.072	698,281		13	44
14	32.90	—0.75	168,204	198,060	49.9	58.3	74.5	3,374	— 870	4.038	679,285	Calm	13	44
15	32.11	—0.80	166,737	199,282	49.5	58.7	77.5	3,370	+1,222	4.003	667,581	VI—10	13	44
16	31.28	—0.80	162,766	198,065	48.4	58.3	76.5	3,363	—1,217	3.898	634,381	VII—5	13	44
17	30.35	—0.90												
18	29.80	—0.55												
19	29.03	—0.70	154,928	197,771	46.2	58.2	73.5	3,352	— 294	3.774	584,724	XI—12	14	44
20	28.61	—0.50	151,785	196,035	45.4	57.7	73.5	3,344	—1,736	3.693	560,548	X—3	15	44
21	28.05	—0.60	150,494	196,616	45.1	57.9	73.0	3,339	+ 581	3.721	559,923	X—4	15	44
22	27.46	—0.60	147,808	195,901	44.3	57.7	71.5	3,337	— 715	3.620	535,052	I—8	15	44
23	26.94	—0.50	147,378	197,210	44.2	58.1	72.0	3,335	+1,309	3.556	523,559	XI—5	15	44
24	26.65	—0.25												
25	26.21	—0.40	144,973	197,244	43.5	58.1	70.5	3,334	+ 84	3.574	518,191	X—10	15	44
26	26.15	—0.05	144,894	197,366	43.5	58.1	70.5	3,334	+ 122	3.508	508,266	X—6	15	44
27	27.07	+0.65	147,695	197,093	44.3	58.1	71.0	3,336	— 278	3.715	548,655	V—5	15	44
28	28.41	+1.80	152,389	197,308	45.6	58.1	72.0	3,334	+ 215	3.899	594,094	XI—20	15	44
29	30.16	+1.60	157,690	196,741	47.0	58.0	74.0	3,355	— 567	3.976	626,972	II—10	15	44
30	31.24	+1.10	160,617	196,051	47.8	57.7	74.0	3,363	— 690	3.997	641,959	V—6	15	44
31	31.85	+0.50												

| Apr. | | |

MEMORANDA TO ACCOMPANY TABULATED RESULTS OF FINAL REDUCTION IN SECRETARY'S OFFICE, MISSISSIPPI RIVER COMMISSION, OF DISCHARGE OBSERVATIONS MADE AT WILSON'S POINT, LOUISIANA, 1883–1890, AND AT BREAK IN SKIPWITH LEVEE, MISSISSIPPI, 1890.

The discharge section was located at Wilson's Point Landing in November, 1883, and the same location, or about the same location, has been used throughout the different series to May 7, 1890. When first located the section crossed the head of Cottonwood Bar, but owing to the movement of the bar down-stream the form of the section has changed, and the caving of the banks has also increased the width of the section.

The methods used in this reduction are essentially the same as those heretofore employed in this office and fully described in the Annual Report Mississippi River Commission, 1887. A slight change, however, has been made since that report in computing the discharge, which has been found throughout this work as follows:

Each partial area was multiplied by the total number of meter registrations at the corresponding velocity station, and the sum of these products, after being reduced to registrations per second, was multiplied by the meter constant a; to this product was added the product of the total area into the meter constant b; the sum of these giving the total discharge when the meter had been run at the standard six-tenths depth from the surface.

The datum line was assumed at the same elevation throughout the different series 41.83 feet on the local gauge.

As the observations of the different years were not all under the same direction, the notes pertaining to the different periods are given as follows:

1883–1885.—Mr. E. D. Thompson, assistant engineer, chief of party.

A report on the field work of these observations to September 17, 1884, was published in the report of the Mississippi River Commission, 1884, page 270. The results of the first computation were published in the reports of the Commission, 1884 and 1885, pages 274 and 2968, respectively.

A copy of the field-notes of the whole series was received from the office of the third district in 1886 for recomputation in this office. Tracings of the cross-sections had previously been received from the third district, drawn to a scale of $1'' = 20'$ vertical and $1'' = 200'$ horizontal; the plotting of these was checked from the copy of field-notes above referred to, and made to agree with them.

The notes do not contain any record of tests of lead-line, and give no lead-line corrections.

The W. G. Price current meter No. 4 was used in measuring all the velocities, the registrations or half revolutions were indicated by a telegraph sounder.

Observations were made for rating the meter November 26, 1883; February 25, 1884; April 12, 1884, and January 12, 1885.

All of these observations have been reduced in this office by the method of least squares; the results are given in the following table:

Date.	No. of observations.	a	b	e_0	e_a	e_b
November 26, 1883	20	2.1068	—0.076	±0.1573	±0.04916	±0.1061
February 25, 1884	12	2.1487	+0.2550	±0.3577	±0.2103	±1.4766
April 12, 1884	19	2.15805	+0.00157	±0.1021	±0.0349	±0.0260
January 12, 1885	32	2.06143	+0.1348	±0.0448	±0.0135	±0.0254
January 12, 1885	32	1.98372	+0.2195	±0.1609	±0.0561	±0.1143

The results of all these sets of observations were combined, the different values of the constants being given weight inversely as their probable errors, and the following resulting equation was used in computing all the discharges:

$$y = +2.08\,x + 0.0703.$$

In discharge observations up to and including January 13, 1885, the meter had been run at mid depth, after that date at six-tenths depth from the surface.

It was necessary to correct the discharges so obtained up to January 13 to correspond to six-tenths depth velocity; and for this purpose the co-efficient (0.963) was adopted and applied. This ratio is based on the experimental work of 1882 at Helena,

Hays Landing, and Red River Landing. (See report Mississippi River Commission, 1884, page 199.)

As stated in the field report the velocity stations and soundings were definitely located, but frequently the notes were insufficient to locate the water's edge, and in such case the width of river was taken from the sheets of first computation.

For obtaining the areas of cross-sections, soundings were scaled from the plotted sections at each velocity station and at points midway between the stations; the sum of the distances between soundings was made to agree with the water width given in the notes. From these the areas were computed in the usual manner.

In computing datum areas, datum widths were assumed at 3,472 feet from November 27, 1883, to February 29, 1884, and 3,484 feet from March 3 to May 27, 1884, on and after June 11, 1884, at 3,520 feet. These changes in datum widths were necessitated by change of river width caused by caving banks. The datum areas were computed by the following formula:

Datum area $= (41.83 - h) \frac{W + W'}{2} +$ water area. In which w represents datum width, w' water width, and h reading on local gauge.

On January 26, 1885, two sets of velocity observations were made, one in the forenoon and one in the afternoon; the latter set show a large increase in the channel velocities. The observer states that the conditions under which both sets were made were apparently the same. Discharge for each set has been computed separately, using the same water area, and the results are given separately in the table.

1887-'88.—Mr. Arthur Hider, assistant engineer, chief of party.

1889.—Mr. E. C. Tollinger, assistant engineer, chief of party.

Datum width was taken as 3,555 feet for 1887 and 1888, and 3,646 feet for 1889. For the observations of 1887-'88 the first computation of water areas was checked by planimeter measurements, the sounding notes not being obtainable, and the water widths were scaled from the plotted cross-section.

The results of reduction in secretary's office of observations for rating the meters that were used in observing velocities are given in the following table:

Designation of meter.	Date and locality of rating observations.	Number of observations.	a	b	Mean error of observations.	Mean error of a.	Mean error of b.
Not given ...	April 18, 1887, Old River Lake.	10	+1.9921	+0.3769	±0.0825	±0.0251	±0.0832
Not given	April 23, 1887, Old River Lake.	15	+1.8941	+0.3448	±0.0671	±0.0145	±0.0493
Price, No. 5 ..	July 4, 1889, near Ashton, La.	11	+4.0704	+0.0417	±0.1735	±0.0610	±0.1341

Combining the results of April 18 and 23, 1887, by weighting the constants inversely as the squares of their mean errors, we have

$$y = 1.9186\,x + 0.353,$$

which was the equation used for reducing the observations at Arkansas City and Wilson's Point, 1887 and 1888.

For computing discharges, July 3–5, 1889, the results of rating July 4, given in the above table, were used.

1890.—Mr. F. P. Spalding, chief of party.

The results were obtained in the usual manner, except the discharge over bank east of section, which the observer states "was obtained by taking meter observations and soundings at approximately equal distances and averaging them to give a mean velocity and depth. The measurement of this discharge was not made on line of the section but in three separate parts." The results of the overflow discharge are from the field computation, the observation notes not having been received.

For velocity observations of January 28 and 31, and February 11 and 12 (except at one station on February 11), Price current meter No. 4 was used; the field-notes state that results of a rating previously made at Ashton are, $y = 1.921\,x + 0.321$, in which y = velocity in feet per second and x = registrations of meter per second. These values for this meter have been adopted in the final reduction.

For all other velocity observations Price meter No. 5 was used; 3 sets of rating ob-

servations were made with this meter during the season, the results of which, derived from final reduction in this office, are given in the following table:

Designation of meter.	Date and locality of rating observations.	No. of observations.	a	b	Mean error of observation.	Mean error of a.	Mean error of b.
Price meter No. 5.	Feb. 5, 1890, Duncansby, Miss...	*21	3.7581	+0.271	±0.124	±0.087	±0.151
	Feb. 26, 1890, Wilson's Point, La.	†24	3.7650	+0.2529	±0.048	±0.027	±0.045
	Apr. 11, 1890, Wilson's Point, La.	*29	3.791	+0.2042	±0.145	±0.084	±0.132

* In still water. † In running water.

It is reported that this meter was taken apart and cleaned on February 11, therefore the results of the first rating were used in computing discharges to February 11. For river discharges after that date the equation $y = 3.7675\,x + 0.2479$ was used; this was obtained by combining the results of ratings made February 26 and April 11, giving weight to the values of a and b inversely as the squares of their mean errors in the two series.

For computing discharges through the break in Skipwith levee, since the velocities were low, the results of April 11 rating were used, as they agree more closely with former ratings of this meter where low velocities were observed.

Datum was assumed at 41.83 feet on the local gauge as in computation of previous Wilson's Point discharge measurements.

OFFICE SECRETARY MISSISSIPPI RIVER COMMISSION,
May 30, 1890.

Results of discharge observations, Mississippi River, Wilson's Point, Louisiana.

METHOD.—Price meter, at mid-depth; observed velocities multiplied by 0.963 to reduce to six-tenths depth from the surface.

Date.	Gauges.			Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	No. of velocity stations.	No. of soundings.
				Area.		Depth.			Width.					
	Lake Providence.	Local.*	Rise or fall in the preceding 24 hours.	Water.	Below datum.	Mean.	Mean datum.	Maximum.						
1883.	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*		
Nov. 27	17.9	.....	—0.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
28	18.4	23.00	+0.5	114,532	179,068	33.9	51.6	83.0	3,383	.....	4.287	490,949	20	41
Dec. 8	24.8	28.90	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	24.4	28.90	—0.2	131,875	176,193	39.0	50.7	85.0	3,383	— 2,875	4.892	645,188	12	62
1884.														
Jan. 30†	25.5	29.60	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	11	.....
31†	25.3	29.69	—0.2	129,949	172,129	37.9	49.6	75.0	3,425	— 4,064	5.027	653,251	11	53
Feb. 15	34.6	38.42	+0.6	16[illegible],309	172,139	46.2	49.6	86.0	3,467	+ 10	5.399	865,470	11	33
26	37.4	41.22	—0.4	176,264	178,382	50.8	51.4	88.0	3,472	+ 6,243	5.851	1,031,322	11	45
27	37.6	41.29	+0.2	172,814	174,689	49.8	53.2	86.0	3,472	— 3,698	6.128	1,058,945	11	39
28	37.6	41.35	0.0	172,855	174,521	49.8	50.8	88.0	3,472	— 168	5.878	1,015,993	11	31
29	37.7	41.40	+0.1	178,584	180,077	51.4	51.9	91.5	3,472	+ 5,556	5.799	1,035,667	11	44
Mar. 3	37.7	41.43	0.0	175,251	176,645	50.3	50.7	88.0	3,484	— 3,432	5.824	1,020,615	11	42
6	37.8	41.58	+0.1	180,344	181,215	51.8	52.0	88.0	3,484	+ 4,570	5.775	1,041,557	11	45
11	38.1	41.83	0.0	186,032	186,032	53.4	53.4	90.0	3,484	+ 4,817	6.098	1,134,373	11	47
13	38.2	41.78	0.0	183,017	183,191	52.5	52.6	89.0	3,484	— 2,841	6.026	1,102,709	11	59
17	37.8	41.58	0.0	184,563	185,434	53.0	53.2	87.0	3,484	+ 2,243	5.820	1,075,866	11	56
19	38.0	41.61	0.0	184,632	185,418	53.0	53.2	89.0	3,484	— 16	5.661	1,045,312	11	54
21	38.3	41.77	+0.2	186,930	187,139	53.7	53.7	89.0	3,484	+ 1,721	5.369	1,003,592	11	56
24	38.4	41.80	0.0	188,075	188,180	54.0	54.0	89.0	3,484	+ 1,041	5.572	1,047,887	12	55
26	38.3	41.67	0.0	186,222	186,779	53.5	53.6	86.5	3,484	— 1,401	5.434	1,011,849	11	57
28	38.1	41.53	—0.1	185,573	186,618	53.3	53.6	86.0	3,484	— 161	5.331	969,223	11	52
Apr. 5	37.1	40.80	—0.1	188,261	191,850	54.0	55.1	85.0	3,484	+ 5,282	5.415	1,019,427	11	53
12	36.7	40.55	0.0	188,173	192,633	54.0	55.3	85.5	3,484	+ 783	5.317	1,000,579	11	56
16	36.7	40.70	0.0	185,409	189,346	53.2	54.3	85.0	3,484	— 3,287	5.509	1,021,507	11	49
24	36.7	40.68	0.0	188,908	192,915	54.2	55.4	88.0	3,484	+ 3,569	5.373	1,015,038	11	52
May 3	36.5	40.45	0.0	190,696	195,504	54.7	56.1	88.0	3,484	+ 2,589	5.308	1,012,169	11	56
10	36.5	40.55	0.0	182,895	187,855	52.5	53.8	86.0	3,484	— 8,149	5.293	967,981	11	81
16	36.4	40.35	—0.1	186,487	191,613	53.5	55.0	85.5	3,484	+ 4,288	5.312	990,695	11	78
27	34.5	38.45	—0.4	182,876	194,649	52.5	55.9	85.0	3,482	+ 3,006	4.871	890,789	11	60
June 11	24.5	29.07	—0.2	147,996	192,707	42.4	54.7	75.0	3,488	— 1,942	3.947	584,068	11	59
17	25.0	29.45	+0.2	147,738	191,161	42.3	54.3	74.0	3,495	— 1,546	4.176	617,007	11	66
23	25.5	30.16	0.0	153,326	194,404	43.6	55.2	75.0	3,520	+ 3,243	4.021	616,542	11	60
28	24.4	29.19	—0.3	147,183	191,657	41.8	54.4	73.5	3,517	— 2,747	4.119	606,217	11	62

* Zero is at the same elevation as zero of Lake Providence gauge = 89.62 feet above Cairo datum plane, survey Mississippi River.
† These observations were taken in fog and rain with the river full of drift. Meter worked very badly.

Results of discharge observations, Mississippi River, Wilson's Point, Louisiana—Continued.

Date.	Gauges.			Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	No. of velocity stations.	No. of soundings.
				Area.		Depth.			Width.					
	Lake, Providence.	Local.*	Rise or fall in the preceding 24 hours.	Water.	Below datum.	Mean.	Mean datum.	Maximum.						
1884.	*Feet.*	*Feet.*	*Feet.*	*Sq. Feet.*	*Sq. Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. Feet.*	*Feet.*	*Cubic Feet.*		
July 7	21.6	26.65	—0.2	135,389	188,454	38.9	53.5	69.5	3,478	— 3,203	4.045	547,467	11	61
22	18.9	24.18	—0.2	133,312	195,043	38.4	55.4	70.0	3,475	+ 6,589	3.936	524,782	11	68
Aug. 14	15.0	20.36	—0.2	115,222	190,388	33.1	54.1	66.0	3,482	— 4,655	3.210	369,906	11	65
Sept. 17	7.2	12.44	—0.4	90,502	193,176	26.1	54.9	58.0	3,467	+ 2,788	2.799	253,330	11	62
Oct. 21	13.9	19.12	+0.2	115,473	194,549	33.5	55.3	67.5	3,444	+ 1,373	3.276	378,308	11	59
Nov. 25	6.8	11.58	0.0	89,647	194,917	26.1	55.4	62.0	3,440	+ 368	2.745	246,115	11	66
1885.														
Jan. 31	20.5	25.53	+2.3	123,299	180,333	35.5	51.2	72.0	3,478	−14,584	3.880	478,439	12	51
Feb. 8	27.8	32.91	+1.1	156,648	187,890	44.9	53.4	75.0	3,485	+ 7,557	5.005	784,010	12	57
13	30.6	35.03	+0.2	166,521	193,390	48.8	54.9	79.5	3,502	+ 5,400	5.750	974,761	12	55
21	33.9	37.68	+0.2	174,788	189,363	49.9	53.8	78.5	3,504	— 3,927	5.234	914,925	11	48
26	34.5	38.12	0.0	176,731	189,761	50.4	53.9	79.0	3,504	+ 398	{6.327 ‡ / 6.696 §}	{‡1,118,265 / §1,183,457}	{10 / 11}	68
29	34.6	38.31	0.0	177,942	190,304	50.8	54.1	79.0	3,504	+ 543	5.334	948,073	21	72
Mar. 6	33.8	37.46	—0.5	182,185	197,535	52.0	56.1	79.0	3,505	+ 7,231	5.116	932,134	22	69
14	28.4	32.09	—0.4	157,090	191,292	44.8	54.3	72.0	3,503	— 6,243	4.368	686,192	24	77
19	27.2	31.05	0.0	160,589	198,438	45.9	56.4	71.0	3,502	+ 7,146	4.228	695,079	23	81
25	24.8	28.72	—0.8	150,902	196,918	43.2	55.9	68.0	3,500	— 1,520	4.044	610,245	23	85
Mar. 5	17.6	22.02	+0.1	123,738	192,964	35.7	54.8	62.0	3,469	— 3,954	3.521	435,721	22	97
13	20.9	†25.37	+1.0	138,169	195,845	39.7	55.6	66.0	3,488	+ 2,881	3.968	548,235	22	79
1887.														
Apr. 19	22.8	27.23	—1.3	139,309	191,139	39.3	53.8	60.0	3,545	.....	3.888	541,673	12	40
1888.														
Apr. 23	38.0	41.63	+0.1	179,815	180,526	50.7	50.9	72.0	3,550	.....	6.452	1,160,172	11	34
23	38.1	41.68	+0.1	177,905	178,438	50.1	50.3	71.0	3,550	— 2,088	6.392	1,137,256	11	28
24	38.1	41.63	0.0	174,672	175,388	49.1	49.3	69.0	3,555	— 3,035	6.036	1,051,818	11	29
25	38.1	41.63	0.0	181,421	182,132	51.0	51.2	73.0	3,556	+ 6,749	6.000	1,088,456	11	32
26	38.0	41.56	—0.1	188,075	189,034	53.0	53.2	72.0	3,550	+ 6,902	6.374	1,198,871	11	27
27	37.8	41.43	—0.2	179,252	180,671	50.6	50.8	73.0	3,542	— 8,363	6.250	1,120,357	11	29
1889.														
July 3	29.2	33.03	—0.2	133,739	165,736	36.9	45.5	75.0	3,626	.....	6.388	854,370	11	25
4	28.9	32.70	—0.3	132,462	165,659	36.5	45.4	76.5	3,626	— 77	6.489	859,553	11	26
5	28.3	32.13	—0.6	129,388	164,648	35.7	45.2	76.5	3,624	— 1,011	6.116	791,386	11	25

* Zero is at the same elevation as zero of Lake Providence gauge = 89.62 feet above Cairo datum plane, survey Mississippi River.
† These observations taken under unfavorable circumstances and amid much floating drift. ‡ a.m. § p.m.

Results of discharge observations, Mississippi River, Wilson's Point, Louisiana—Continued.

Date.	Gauges.			Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Discharge over bank, east of section, per second.†	Total discharge of river, per second.	No. of velocity stations.	No. of soundings.
	Lake Providence.	Local.*	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.							
				Water.	Below datum.	Mean.	Mean datum.	Maximum.								
1890.	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*		
Jan. 28	34.9	38.73	+0.3	147,690	159,296	39.4	42.5	78	3,744	.....	7.386	1,090,788	.....	1,090,788	10	48
29	35.2	.....	+0.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....
30	35.6	.....	+0.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....
31	36.1	39.83	+0.5	153,046	160,534	40.9	42.9	79	3,744	+ 1,286	6.971	1,066,966	.....	1,066,966	10	41
Feb. 1	36.4	.....	+0.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....
2	36.8	.....	+0.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....
3	37.1	40.79	+0.3	153,814	157,707	41.1	42.1	80	3,744	+ 2,827	7.499	1,153,454	.....	1,153,454	10	46
4	37.4	41.03	+0.3	165,766	168,761	44.3	45.1	82	3,744	+11,054	7.029	1,165,164	.....	1,165,164	10	49
5	37.5	41.25	+0.1	159,219	161,391	42.5	43.1	81	3,744	+ 7,370	6.870	1,098,796	5,000	1,098,796	10	52
6	37.8	41.42	+0.3	163,783	165,818	43.7	44.2	82	3,744	+ 8,927	6.847	1,121,471	8,000	1,129,471	10	43
7	38.2	.....	+0.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....
8	38.3	41.93	+0.1	171,563	.....	45.8	.....	.....	3,744	.....	6.874	1,179,385	16,000	1,195,385	10	142
9	38.4	.....	+0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....
10	38.5	42.22	+0.1	178,861	177,363	47.8	47.4	81	3,744	+12,045	6.834	1,222,351	20,000	1,242,351	10	40
11	38.6	42.28	+0.1	175,172	173,487	46.8	46.3	81	3,744	— 3,876	6.696	1,172,852	23,000	1,195,852	10	42
12	38.6	42.27	0.0	173,290	171,643	46.3	45.8	80	3,744	— 1,844	6.403	1,109,604	23,000	1,132,604	10	38
13	38.6	42.28	0.0	174,141	172,456	46.5	46.1	80	3,744	+ 813	6.317	1,100,104	23,000	1,123,104	10	40
14	38.7	42.39	+0.1	177,392	175,295	47.4	46.8	80	3,744	+ 2,839	6.830	1,122,924	25,000	1,147,924	10	41
15	38.7	42.39	0.0	171,602	169,505	45.8	45.3	80	3,744	— 5,790	6.190	1,062,233	25,000	1,087,233	10	41
16	38.7	.....	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....
17	38.8	42.45	+0.1	175,514	173,193	46.9	46.3	80	3,744	+ 3,688	6.137	1,077,060	26,000	1,103,060	10	42
18	38.8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....
19	38.9	.....	+0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....
20	39.0	42.78	+0.1	177,728	174,171	47.5	46.5	80	3,744	+ 978	5.982	1,063,254	28,000	1,091,254	10	38
21	39.1	42.83	+0.1	179,984	176,240	48.1	47.1	80	3,744	+ 2,069	6.327	1,138,692	28,000	1,166,692	10	41
22	39.2	42.98	+0.1	182,286	177,980	48.7	47.5	80	3,744	+ 1,740	6,012	1,095,979	29,000	1,124,979	10	42
23	39.3	.....	+0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....
24	39.4	43.21	+0.1	178,931	173,764	47.8	46.4	81	3,744	— 4,216	6.221	1,113,174	30,000	1,143,174	10	41
25	39.5	43.27	+0.1	181,393	176,002	48.4	47.0	80	3,744	+ 2,238	6.106	1,107,519	30,000	1,137,519	10	44
26	39.5	43.27	0.0	180.075	174,684	48.1	46.7	80	3,744	— 1,318	5.970	1,075,181	30,000	1,105,181	10	40
27	39.5	43.38	0.0	183,736	177,933	49.1	47.5	80	3,744	+ 3,249	5.786	1,063,172	31,000	1,094,172	10	42
28	39.5	.....	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....

* Zero at same elevation as zero of Lake Providence gauge = 89.62 feet above the Cairo datum plane, survey Mississippi River.
† From field computation, by chief of party. ‡ Interpolated.

Results of discharge observations, Mississippi River, Wilson's Point, Louisiana—Continued.

Date.	Gauges.			Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Discharge over bank, east of section, per second.	Total discharge of river, per second.	No. of velocity stations.	No. of soundings.
	Lake Providence.	Local.*	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.							
				Water.	Below datum.	Mean.	Mean datum.	Maximum.								
1890.	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*		
Mar. 1	39.4	43.18	−0.1	179,789	174,735	48.0	46.7	80	3,744	— 3,198	5.801	1,043,044	30,000	1,073,044	10	42
2	39.4		0.0												10	
3	39.4	43.23	0.0	183,555	176,313	49.0	47.6	80	3,744	+ 3,578	5 911	1,084,915	30,000	1,114,915	10	41
4	39.5	43.31	+0.1	184,903	179,362	49.4	47.9	81	3,744	+ 1,049	5.907	1,092,207	31,000	1,123,207	10	44
5	39.6	43.45	+0.1	185,679	179,614	49.6	48.0	80	3,744	+ 252	5.942	1,103,277	33,000	1,136,277	10	35
6	39.8	43.53	+0.2	190,692	184,327	50.9	49.2	80	3,744	+ 4,713	6.006	1,145,360	34,000	1,179,360	10	42
7	40.0	43.81	+0.2	193,048	185,635	51.6	49.6	81	3,744	+ 1,308	5.814	1,122,867	40,000	1,162,867	10	43
8	40.2	43.93	+0.2	195,692	187,830	52.3	50.2	81	3,744	+ 2,195	5.840	1,142,839	43,000	1,185,839	10	43
9	40.3		+0.1												10	
10	40.4	44.26	+0.1	197,730	188,632	52.8	50.4	81	3,744	+ 802	5.973	1,180,951	47,000	1,227,951	10	42
11	40.5	44.30	+0.1	199,068	189,820	53.2	50.7	82	3,744	+ 1,188	6.238	1,241,797	47,000	1,288,797	10	37
12	40.7	44.56	+0.2	202,916	192,695	54.2	51.5	81	3,744	+ 2,875	5.621	1,140,538	50,000	1,190,538	10	43
13	40.9	44.68	+0.2	203,930	193,260	54.5	51.6	81	3,744	+ 565	5.533	1,128,406	50,000	1,178,406	10	42
14	40.9	44.71	0.0	205,205	194,422	54.8	51.9	81	3,744	— 1,162	5.675	1,164,569	50,000	1,214,569	10	42
15	41.0	44.81	+0.1	199,598	188,436	53.3	50.3	82	3,744	— 5,986	5.865	1,170,525	50,000	1,220,525	10	43
16	40.9		−0.1												10	
17	40.7	44.73	−0.2	200,443	189,585	53.5	50.6	81	3,744	+ 1,149	5.914	1,185,377	47,000	1,232,377	10	42
18	40.6	44.69	−0.1	199,451	188,743	53.3	50.4	82	3,744	— 812	6.109	1,218,413	45,000	1,263,413	10	43
19	40.4	44.43	−0.2	197,027	187,293	52.6	50.0	81	3,744	— 1,450	6.056	1,193,168	38,000	1,231,168	10	43
20	40.3	44.30	−0.1	199,990	190,742	53.4	50.9	81	3,744	+ 3,449	5.654	1,130,711	35,000	1,165,711	10	43
21	40.2	44.29	−0.1	200,678	191,468	53.6	51.1	80	3,744	— 726	5.433	1,090,294	35,000	1,125,294	10	43
22	40.3		+0.1												10	
23	40.2		−0.1												10	
24	40.2	44.31	0.0	201,354	192,069	53.8	51.3	80	3,744	— 601	5.824	1,172,684	35,000	1,207,684	10	43
25	40.2	44.33	0.0	200,431	191,071	53.5	51.0	80	3,744	— 998	6.082	1,218,946	35,000	1,253,946	10	43
26	40.2		0.0												10	
27	40.0		−0.2												10	
28	39.9	44.05	−0.1	199,361	191,049	53.2	51.0	79	3,744	— 22	5.947	1,185,677	30,000	1,215,677	10	42
29	39.8		−0.1												10	42
30	39.6		−0.2												10	42
31	39.6	43.58	0.0	196,146	189,594	52.4	50.6	78	3,744	— 1,455	5.982	1,173,386	25,000	1,198,386	10	42
Apr. 1	39.6														10	42
2	39.5	43.55	−0.1	195,601	189,161	52.2	50.5	78	3,744	— 483	5.489	1,144,165	23,000	1,167,165	10	42
3	39.6	43.68	+0.1	195,887	188,961	52.3	50.5	79	3,744	— 200	6.034	1,182,027	23,000	1,205,027	10	42
4	39.4	43.43	−0.2	195,501	190,511	52.5	50.9	78	3,744	+ 1,550	5.979	1,174,924	21,500	1,196,424	10	42
5	39.3	43.28	−0.1	196,828	190,399	52.3	50.9	79	3,744	— 112	3,732	1,122,393	20,000	1,142,393	10	42
6	39.3		0.0												10	42

	7	39.3	43.28	0.0	195,314	189,885	52.2	50.7	78	3,744	— 514	5.776	1,128,112	19,000	1,147,112	10	42
	8	39.3	43.28	0.0	195,719	190,290	52.3	50.8	78	3,744	+ 405	5.701	1,115,742	18,000	1,133,742	10	42
	9	39.3	43.28	0.0	196,042	190,613	52.4	50.9	78	3,744	+ 323	5.622	1,102,056	17,000	1,119,056	10	42
	10	39.3	43.23	0.0	192,041	186,799	51.3	49.9	78	3,744	— 3,814	5.728	1,099,945	16,000	1,115,945	10	42
	11	39.3	43.23	0.0	191,806	186,566	51.2	49.8	77	3,744	— 233	5.712	1,095,566	15,000	1,110,566	10	42
	12	39.3	43.23	0.0	193,538	188,296	51.7	50.3	78	3,744	+ 1,730	5.909	1,143,563	15,000	1,158,563	11	41
	13	39.3	.....	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11	42
	14	39.3	43.23	0.0	192,974	187,732	51.5	50.1	77	3,744	— 564	5.588	1,078,298	15,000	1,093,298	11	42
	15	39.2	43.13	—0.1	194,324	189,457	51.9	50.6	77	3,744	+ 1,725	5,604	1,088,952	14,000	1,102,952	11	42
	16	39.3	.....	+0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11	42
	17	39.3	43.13	0.0	194,305	189,438	51.9	50.6	78	3,744	— 19	5.518	1,071,221	14,000	1,085,221	11	42
	18	39.2	43.08	—0.1	194,147	189,467	51.9	50.6	77	3,744	+ 29	5.566	1,080,669	13,000	1,093,669	11	42
	19	39.3	43.01	+0.1	195,489	191,071	52.2	51.0	77	3,744	+ 1,604	5.523	1,079,777	12,000	1,091,777	11	42
	20	39.3	.....	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11	42
	21	39.3	43.05	0.0	191,652	187,084	51.2	50.0	77	3,744	— 3,987	5.701	1,092,657	12,000	1,104,657	11	42
	22	39.3	43.04	0.0	192,149	187,619	51.3	50.1	77	3,744	+ 535	5.603	1,076,696	12,000	1,088,696	11	42
	23	39.3	.....	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11	42
	24	39.4	43.06	+0.1	194,273	189,593	51.9	50.6	77	3,744	+ 1,974	5.736	1,114,351	12,000	1,126,351	11	42
	25	39.3	43.01	—0.1	194,199	189,781	51.9	50.7	76	3,744	+ 188	5.628	1,092,930	11,000	1,103,930	11	42
	26	39.1	42.78	—0.2	196,909	192,252	52.3	51.4	77	3.744	+ 2,571	5.563	1,089,843	9,000	1,098,843	11	42
	27	38.9	.....	—0.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11	42
	28	38.7	42.33	—0.2	189,429	187,557	50.6	50.1	75	3,744	— 4,795	5.479	1,037,800	5,000	1,042,800	11	42
	29	38.5	42.13	—0.2	189,457	188,334	50.6	50.3	76	3,744	+ 777	5.431	1,028,916	0	1,028,916	11	42
	30	38.4	42.01	—0.1	186,693	186,019	49.6	49.7	75	3,744	— 2,315	5.524	1,031,336	0	1,031,336	11	42
May	1	38.3	.....	—0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	42
	2	38.2	41.81	—0.1	185,774	185,849	49.6	49.6	75	3,744	— 170	5.501	1,021,930	0	1,021,930	10	42
	3	38.1	.....	—0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	4	38.1	.....	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	5	38.0	41.78	—0.1	189,393	189,767	50.6	50.7	75	3,744	+ 3,918	5.372	1,017,338	0	1,017,338	10	43
	6	37.9	41.58	—0.1	189,918	190,854	50.7	51.0	73	3,744	+ 1,087	5.344	1,014,895	0	1,014,895	10	42
	7	37.9	41.48	0.0	189,628	190,938	50.6	51.0	.....	3,744	+ 84	5.172	980,701	0	980,701	10	(1)23

* Zero at same elevation as zero of Lake Providence gauge = 89.62 feet above the Cairo datum plane, survey Mississippi River.

NOTE.—Velocities were observed with Price current meters, Nos. 4 and 5, at six-tenths depth from the surface as mean velocity at each velocity station.

Results of discharge observations at break in Skipwith Levee, Mississippi.

Date.	Gauges.			Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Method.
				Area.		Depth.			Width.				
	Lake Providence.	Wilson's Point discharge section.	Rise or fall in the preceding 24 hours.	Water.	Below datum.	Mean.	Mean datum.	Maximum.					
1890.	*Feet.*	*Feet.*	*Feet.*	*Square feet.*	*Square feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Square feet.*	*Feet.*	*Cubic feet.*	
Apr. 2	39.5	43.55	−0.1	34,118	.....	33.4	.....	52	1,020	.....	1.867	63,704	Meter at surface.*
5	39.3	43.28	−0.1	39,525	.....	35.9	.....	50	1,100	.....	2.037	82,870	Meter 0.6 of depth from surface.
9	39.3	43.28	0.0	39,684	.....	32.8	.....	51	1,210	.....	1.877	74,480	
14	39.3	43.23	0.0	40,424	.....	32.6	.....	51	1,240	.....	1.920	77,648	
16	39.3	43.13	+0.1	41,875	.....	33.8	.....	50	1,240	.....	1.772	74,188	
19	39.3	43.01	+0.1	41,014	.....	33.1	.....	48	1,240	.....	1.548	63,477	
24	39.4	43.08	+0.1	42,508	.....	33.7	.....	46	1,260	.....	1.669	70,954	
28	38.7	42.33	−0.2	42,210	.....	33.5	.....	48	1,260	.....	1.521	64,210	
May 1	38.3	41.91	−0.1	39,970	.....	31.7	.....	51	1,260	.....	1.063	42,487	
6	37.9	41.58	−0.1	38,728	.....	30.7	.....	45	1,260	.....	0.996	38,566	

* Four-fifths of surface velocity is taken as mean velocity at velocity stations.

NOTES.—The break is 529 miles below Cairo and near Skipwith, Miss. The measurements were taken on a section in line with the ends of the broken levee. There is a small excess of computed discharge, since the direction of the flow was not perpendicular to the section.

Zeros of both gauges are 89.62 feet above Cairo datum plane, survey Mississippi River.

REPORT OF CAPTAIN CHARLES F. POWELL, CORPS OF ENGINEERS, IN CHARGE OF SURVEY OF THE MISSISSIPPI RIVER.

MISSISSIPPI RIVER COMMISSION,
OFFICE OF THE SECRETARY,
St. Louis, Mo., June 5, 1890.

The field work of topography and hydrography was resumed in early August, 1889, at next above Chester, Ill., and carried to Alton, Ill., by the end of November, when the work was stopped for the year, making 94 miles of main river and 22 miles of old river and tributaries. A report of operations by Mr. C. M. Winchell, chief of party, is attached.

The topographic and hydrographic field work is now continued from Donaldsonville, La. The triangulation, reduced, still ends at Keokuk, Iowa, and the precise levels, also reduced, at Fulton, Ill., 179 and 350 miles, respectively, above Alton.

Of the mapping, the manuscript detail sheets were finished to Chester, and about one-quarter of the twenty-six sheets from Chester to Alton completed; four of 7-inch-mile manuscript sheets, Cairo to Alton, were partly drawn, and the ten new-edition sheets of the same scale, below Cairo, were completed; the preparation of the manuscript detail sheets for reduction and publication as sixty-nine charts, scale 20,000, Donaldsonville to near Commerce, Mo., which work was in hand at date of last report, was completed, and the last material forwarded to the printer some time ago; the material of six sheets out of seventeen, from Commerce to Alton, was partly prepared.

Of the published charts, editions of thirty-six numbers of the 20,000-scale series were completed, leaving fifteen from Donaldsonville to Commerce to be printed, which should be all done by August. The work of photolithographing and printing the ten new edition inch-mile charts was awarded in succession to the lowest three bidders; the first two failed after reasonable trial to furnish the required quality of work and the job was withdrawn from them. Chart No. 1 is now printed, although the edition is not yet received; and work has been begun on four other sheets.

The gauge records of the river and tributaries, except the Missouri for 1887 and 1888 and 1889, were published in two volumes of stages, etc. The reductions to the present engineer gauges of gauge readings preceding 1880 at Cairo, Vicksburgh, and Natchez were carefully revised by a study of all the notes of the connections at times of gauge shiftings or re-establishments. It was found from the records that the Natchez readings before 1860, as published in the report for 1889, were generally a few tenths too large, and that the highest reading, that for 1862, was 49.9 instead of 50.3; also that the Vicksburg high-water readings before the same year were each 2 feet too large, and that the published 1862 reading of 51.2 was somewhat doubtful, one authority placing it less than 49.3 and one connection at 49.1. At Natchez there is one link of the reduction of the Delta-survey gauges not verified. Search was made for data and some found for reducing the Delta-survey gauges to present gauges at Columbus, Lake Providence, and Red River Landing, but the results are not considered reliable and are therefore not quoted.

Captain Willard, in charge of water-gauges on the Mississippi, has obtained the old Delta note-books, and has kindly undertaken to go over the whole matter, have search made from the old benches, and new levels run to the present gauges. It is expected to subsequently publish, when the matters are definitely settled as far as possible, a new table of the highest and lowest yearly gauge readings at the different stations, correcting at the same time some typographical errors in the table of last report.

After the conclusion of late New Madrid discharge observations, for which a party and instruments were sent from here at request of the first district engineer, this party leveled from the New Madrid gauge to the precise benches at Tiptonville for checking the reduction of that gauge zero to the datum. The 1890 high-water slope around the bend at this locality was also determined by the party. The plot of the adopted high-water grade line of 1889 appeared anomalous at New Madrid, and it was desired to clear up the matter. A small change resulted from the leveling in the elevation of the gauge zero, and the point of change of slope in the actual high-water line was found to be a few miles below the gauge; otherwise the irregularities noticed in the plotted grade line proved to be apparent only, and the good explanation for them remaining is the circumstance of high banks along the bend, and the fact that the river, as in no other place in its whole length, flows north, or directly against its flood plane for 10 miles, thereby elevating the water for increased head, and giving more slope when resuming the direction of the flood plane.

The tide gauge records at Biloxi, Miss., was reduced, tabulated, and plotted; they were also examined in connection with the Signal-Service observations of wind, atmospheric pressure, and rain at New Orleans, Port Eads, and Mobile with the result that wind especially and atmosphere have had appreciable effects on the observed elevations of the water surface, but that it is impracticable to measure by the record

their variations from the mean effect of these elements. It appears that the arithmetical mean of the monthly mean gauge readings will give the best value, from the observations, of mean Gulf level; this mean is about 0.3 of a foot less than the provisionally adopted value. Since the monthly means are rather discordant, it is desirable by multiplying the observations to use those for nearly one year whose consideration had been omitted on account of an irregularity in their record. An effort is to be made to discover the amounts of the irregularity and therefore the proper corrections.

A volume was published during the year of data of permanent points of the river survey and gauge bench-marks below Cairo whose elevations have been determined for convenient use in the field and to better secure reductions in local surveys and levelings to the general survey datum; several copies of the volume have been furnished the district officers and levee engineers. A compilation is being made from all notes and reports of locations, descriptions, and elevations of flood marks or benches, more particularly for use in leveling to later flood marks, a great many of which were made of the late high water, and whose descriptions have been kindly furnished by numerous volunteer observers or agents detailed by the district and levee engineers.

Of the more permanent *personnel* on the river survey, Mr. C. W. Clark has continued as principal assistant in the drawing division, and Messrs. J. A. Ockerson and C. M. Winchell have been connected with the topographical part. Messrs. Wood, Maltby, Connet, and French, topographers, left the work for more lucrative or permanent employment elsewhere. Mr. Dunaway, formerly rodman and recorder, but retained in the office topographical division, and Messrs. Field and Ritter, levelers, also left; it is expected that the latter will return in time for the next field season.

The survey fleet, consisting of the steamer *Patrol* and two survey boats, belonging on the Commission property return, and a steam-launch, are laid up in Alton Slough. The pieces are in good condition and ready for service.

By having a steamer with the survey party last season the work was made to progress up-stream and to be continuous; short and frequent moves of the survey boats were permitted, thus materially saving time in going to and from the daily work. Two moves were made last season without the aid of the *Patrol*, as it was necessary to dock her and make repairs below the water-line. A careful comparison of actual cost of field work by having the steamer with the survey boats and not shows a small decrease for the former; another advantage is more room for drawing, etc., when in the field.

The balance of funds on hand increased by $75,000 will permit, it is estimated, (1) the publication of maps to Alton; (2) extension of precise levels to Duluth, including reduction; (3) publications of maps for 125 miles beyond Alton, including needed field work therefor; and (4) triangulation and its reduction for 50 miles. There is call for the levels from the upper-river improvement work, and when they are run to St. Paul it would be desirable to make a connection, as a closing check, with the mean level of Lake Superior, and thereby with mean tide near New York.

There is no special need in the interests of navigation of the survey beyond St. Paul. The cost of completing the work to that point and publishing the maps in addition to the funds in hand and also in addition to $75,000, the expected appropriation for the coming year, is nearly $225,000; the field work could readily be completed inside of three years with but little addition to the present survey plant, which has only been used for several years to about one-half its capacity during a single season. The provision of the full amount, even if accompanied by annual limit of expenditure of one-third, would much conduce to economy and to the value of the results for the immediate future by preventing a detrimental prolongation of the work. Surveying as a preliminary or accompaniment of navigation improvement work, or as a record of the condition at one period of a changeable water—even one as little changeable as the Upper Mississippi—should for every reason be made with the least practicable delay and in the least practicable time.

Besides the continuance of the survey, there is urgent need, it appears to me, of a hydrographic, low-water survey of the alluvial river. About one-eighth only of the present survey below Cairo was made at low water. The period of field work was from 1857 to 1884; a part, however, having been done since 1870, another part since 1876, and the greater part since 1880. The triangulation, precise levels, and stone-lines are still generally available for new work of topography and hydrography. The estimate of cost, lately submitted, with explanations of this limited resurvey, is $212,526. The work can advantageously be done in four years.

As desired, I have also estimated upon the annual cost of needed local surveys, examinations, investigations, etc., on the lower river, and find the amount to be nearly $45,000; so that in round numbers $175,000 result as the estimated amount which can be profitably expended in the fiscal year 1892 for continuing the survey to St. Paul, and for the hydrographic resurvey, and examinations, investigations, etc., on the

alluvial river. It is suggested that continuing the survey and the resurvey of the alluvial river might well be consolidated in one appropriation item.

Respectfully submitted.

CHAS. F. POWELL,
Captain, Corps of Engineers.

The PRESIDENT OF THE MISSISSIPPI RIVER COMMISSION.

Money statement.

July 1, 1889, amount available		$48,832.95
July 1, 1890, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1889	$44,952.79	
July 1, 1890, outstanding liabilities	1,858.16	
		46,810.95
July 1, 1890, balance available		2,022.00
Amount (estimated) required for completion of existing project to St. Paul		300,000.00
Amount that can be profitably expended in fiscal year ending June 30, 1892		175,000.00
Submitted in compliance with requirements of sections 2 of river and harbor acts of 1866 and 1867.		

List of civilian engineers employed during the year to May 31, 1890, *on work of river and harbor improvement in charge of Capt. Charles F. Powell, Corps of Engineers, and under the river and harbor appropriation act of August* 11, 1888.

Name and place of residence.	Time employed.		Compensation per month.	Where employed.	Work on which employed.
	Months.	*Days.*			
J. A. Ockerson, St. Louis, Mo	4	.....	$200	St. Louis	Survey of Mississippi River.
C. M. Winchell, St. Louis, Mo	11	18	175	In field and at St. Louis.	Do.
Kivas Tully, St. Louis, Mo	10	.....	175	St. Louis	Do.
C. W. Clark, St. Louis, Mo	8	.....	175	St. Louis	Do.
E H. Colby, St. Louis, Mo	.....	7	135	St. Louis	Do.
E L. Harman, St. Louis, Mo	.....	27	130	New Madrid, Mo	Do.
H. W. Baker, St. Louis, Mo	12	.....	175	Madison, Ind., and St. Louis.	General service, improving Mississippi River below the mouth of the Ohio.

REPORT OF ASSISTANT ENGINEER C. M. WINCHELL, CHIEF OF SURVEY PARTY.

ST. LOUIS, MO., *April* 23, 1890.

CAPTAIN: I have the honor to submit the following report on the operations of the field party under my direction during the season of 1889, with a statement of some results of the field measurements of 1888 and some observations upon the river from Cairo to Alton:

In obedience to your instructions the party assembled at St. Louis on August 2, and were conveyed by steamer to Chester, Ill., where the survey boats *Illinois* and *Kentucky*, steam-launch No. 5, and United States steamer *Patrol* were in waiting to receive us.

The organization of the party was the same as in former years: Messrs. F. B. Maltby, G. W. Wood, E. J. Jolley, O. W. Connet, G. H. French, and W. G. Comber, were topographers; J. H. Field and L. E. Ritter, levelers; E. L. Harmon and G. W. Wisner, hydrographers; and G. Bischoff, computer and plotter. The total number of men in the party, including crew of the *Patrol* and galley force, averaged about sixty.

The survey of the river was resumed, where the work of the season before ended, at stone-line 31, in Kaskaskia Cut-off, and at St. Mary's, Mo., in Old River. When the

field season closed in December, 1888, permanent and easily-accessible marks were established both for elevation and position. These were found undisturbed, and the survey continued from them up-stream without any delay on August 3. Having the *Patrol* with the party during the season was a great improvement over former seasons, giving us better quarters and more room both for office work and for sleeping that the quarter-boats alone furnished, and I think also it is more economical to have the *Patrol* with the party to move the boats whenever it is advantageous to move, rather than to depend on outside aid to move from camp to camp. We occupied 20 different camps between Chester and Alton, the moves averaging 5.3 miles each.

The entire season was favorable for survey work both as to stage of river and weather. The river remained at a low stage with only slight fluctuations; from August 3 to November 30 there were only five days when it rained all day, and seven other days that were partly lost on account of showers. On November 30 the survey was completed to Alton, Ill., and work closed on stone-line 61, which passes through Mo. R. C. △ Alton and just above head of Ellis Island.

As in 1888, permanent marks were left at the end of the work whose elevations are known, and the azimuths of lines connecting them determined. December 1 the boats were laid up in the Alton Slough, behind Ellis Island, and the party disbanded.

The survey is based on a system of secondary triangulation done by the Mississippi River Commission in 1880. At the time this triangulation was done, territory points were located on or near the river bank every 3 or 4 miles for the purpose of checking a later topographic survey, but so many of these points were caved into the river, or otherwise destroyed, that it was found necessary to carry a system of tertiary triangulation over the entire reach of river surveyed.

This tertiary triangulation was checked by connection with secondary lines or triangulation stations and by chaining bases every few miles.

TOPOGRAPHY.

Two stadia lines were run along each bank, checking on the tertiary triangulation stations. From these main stadia lines other lines were run back into the country to develop the topographic features and contours. These side lines generally made a circuit, returning to the river and checking on a main-line stake or sounding flag.

On the left bank the country is level, and mostly cultivated, and a strip bordering the river of an average width of 1½ miles was surveyed. From St. Louis to Ste. Genevieve the river follows the bluffs on the right bank. These bluffs are precipitous on their river face, very irregular, being cut up by deep gullies and ravines in all directions. These ravines are full of a growth of small timber and brush and the ridges range from 150 to 400 feet in height above the river. On account of these features it required fully twice as much time and labor to survey the right bank as it did the left. A strip averaging but little more than half a mile in width was surveyed on the right bank.

At Ste. Genevieve the river leaves the bluffs on the Missouri side, crosses the valley, and comes to the foot of the bluffs in Illinois at Kaskaskia near the head of Kaskaskia Cut-off. This Cut-off was caused by the Mississippi caving into the Okaw River in 1881, when it left its old bed via St. Mary's, Mo., and took the channel of the Okaw to Illinois penitentiary at Chester, where it again joins its original channel; this Cut-off is 8¼ miles long and shortens the river 7 miles, it being 15¼ miles around the old channel. The Cut-off has changed from a sluggish narrow stream 75 meters wide to a rapid river averaging more than 200 meters in width. Its maximum width is over 300 meters, and the narrowest place is where it strikes the rocky bluff near its head and makes a sharp turn (about 90 degrees to the south. Here it is only 170 meters wide and is a difficult piece of river to navigate. The old river by St. Mary's is gradually filling up, and is now navigable only at medium to high stages of river.

If the present rate of caving at head of Kaskaskia Island continues it will not be many years before the site of the old town of Kaskaskia will be wiped out of existence. From Kaskaskia the river hugs the Illinois bluffs to Rockwood, about 17 miles. Here it again crosses to the Missouri bluffs at Grand Eddy, and there follows along their base to Cape Girardeau, 44 miles. Immediately below Cape Girardeau is an opening in the bluffs about 4 miles wide, where the first overflow water from the Upper Mississippi enters the head of the St. Francis basin through Niggerwool Swamp.

At Gray's Point the Illinois bluffs approach to within about 1,000 meters of the Missouri bluffs, and from here to Commerce, 7 miles, the river flows over a rocky bed with high bluffs on either side. At Santa Fé the Illinois bluffs trend SE. to the Ohio River.

The Commerce Bluff is a large detached rocky hill, the main line of bluffs leaving the river in a SW. direction at Cape Girardeau.

The last natural rock found in the river above Cairo is Beaver Dam Rock, about 1¼ miles below Commerce, nearly in the main river channel. This rock appears to be a

huge boulder, and at a low-water stage of the river projects more than 3 feet out of the water, and is a constant menace to passing steam-boats.

About 4 miles above Grand Tower, on the east side of the river, is a detached rock hill called Fountain Bluff. This bluff is about 9 miles in circumference and 450 feet high. The west side is very steep; the north side has a rock precipice over 100 feet high, while the east and south sides have a more gradual slope. It is 4 miles west of the main line of bluffs in Illinois.

The highest bluff near the river is Buck Knob, just below Crystal City, which is 488 feet high.

From Alton to Kaskaskia, 87 miles, the bluffs on the east side are from 3 to 10 miles from the river, the widest part of the bottom being opposite and above St. Louis. This entire line of bluff was located and connected with the river; these bluffs have a more gradual slope than the Missouri bluffs, and are not so badly cut up by ravines.

The Okaw was surveyed to where it comes out of the hills, also about 5 miles of the Meremec River, as well as several lakes and streams between the Illinois bluffs and the Mississippi. All the railroad tracks centering in East St. Louis were located across the bottom to where they enter the hills.

From the mouth of the Missouri River to Crystal City, 55 miles, the general course of the river is a little west of south. From Crystal City to Fountain Bluff, 65 miles, it runs southeast. Here it turns more towards the south and only makes about 19 miles of easting from here to Cairo, 84 miles.

Many points, both triangulation and bench-marks, of the survey made by Major Simpson, 1870–1878, were found and connected with, so that changes in the bank-lines since then can be noted by comparing the two surveys; several township and section corners were connected with, as well as four county lines and the stone marking St. Louis City limits. Connection was made with five U. S. Coast and Geodetic Survey triangulation stations on the bluffs east of St. Louis, including their American Bottom base stations. By comparison of M. R. C. with U. S. Coast and Geodetic Survey positions, as determined astronomically, it was found that they differed 134.4 meters in latitude and 33.4 in longitude, the M. R. C. positions being farther south and west. Two of the Missouri River Commission triangulation stations were connected with, also two of their stone-line bench-marks near mouth of Missouri River.

LEVELS.

All elevations are referred to the Memphis datum and are checked by connection with Mississippi River Commission precise level bench-marks.

A continuous line of levels was run along each bank, and once in about 3 miles of river a stone line was established. The levels were duplicated on all stone lines; thirty-one stone lines were established between Chester and Alton. A river crossing of levels was made at each stone line to check the levels on the side of river where there were no P. B. M's. All triangulation stations, permanent marks of other surveys, boundary stones, etc., were touched on and will be tabulated and described in the table of "Permanent marks above Cairo." All water-gauges were connected with and the water-surface at each cross-section determined.

Two U. S. Coast and Geodetic Survey bench-marks on the Eads Bridge were leveled to. Their difference of elevation by our ordinary level river crossing is .001 foot. The Coast Survey published difference is .003 foot. Our ordinary level value of Missouri River Commission bench-mark at mouth of Missouri River differs from their determination of it by 2 feet.

The experience of the last two seasons' survey proves that many of the stone posts used for marking stones, both bench-marks and triangulation stations, have been disturbed. Some are taken by natives and reset for land corners, and used for sills or door-steps, others are broken up by fishermen and used for sinking nets, and several were found cracked and broken in pieces, apparently by fire. It would seem, therefore, that all marks intended to be permanent should be buried beneath the surface or cut on the natural rock with sufficient surface marks so that they can be easily found and identified.

HYDROGRAPHY.

Cross-sections were sounded about every 350 meters and longitudinal along the channel. These soundings were taken from a six-oared yawl-boat and were located by two observers with sextants. In all there were 31,624 casts of the lead between Chester and Alton, and 10,201 double-sextant angles. The deepest water found above Cairo was 112 feet, opposite Grand Tower. The shoal reaches are where the river is wide and dotted with sand-bars and islands, the water being dispersed through several channels. The depth at Kaskaskia Cut-off ranges from 20 to 40 feet; at its mouth it was 70 feet deep. The Okaw at same stage is from 10 to 15 feet deep.

The greatest changes in bank line since Major Simpson's survey, except at Kaskaskia Cut-off, are in Salt Lake Bend. Here the bend has moved east and south about a mile.

The bank is also caving quite rapidly at the lower end of Greenleaf Bend, at Commercial Point, Liberty Bar, and in Sawyer Bend above St. Louis.

Appended are tables showing surface slope of river, discrepancies in levels, and results of tertiary triangulation.

Very respectfully, your obedient servant,

C. M. WINCHELL,
Assistant Engineer.

Capt. CHAS. F. POWELL,
Corps of Engineers.

River slope during survey, being at about low water.

Locality.	Distance.	Slope per mile.	Locality.	Distance.	Slope per mile.
	Miles.	*Feet.*		*Miles.*	*Feet.*
Foot of Kaskaskia Chute to Head Fairy Island	11.0	0.75	Chesley Island to Cliff Cave	6.9	0.68
Head Fairy Island to Mud Landing	5.6	0.67	Cliff Cave to Docks	5.3	0.42
Mud Landing to Bruce Island	6.5	0.64	Docks to foot of Dorcas street	4.9	0.35
Bruce Island to Penitentiary Point	5.3	0.34	Dorcas street to Brooklyn street	4.3	0.34
Penitentiary Point to Durfee Point	5.9	0.64	Brooklyn street to Carrie avenue	3.5	0.59
Durfee Point to Cornice Rock	4.9	0.73	Carrie avenue to near Annie avenue	3.2	1.05
Cornice Rock to Herculaneum	4.3	0.52	Annie avenue to head of Chouteau Island	4.5	0.87
Herculaneum to Glen Park	4.0	0.53	Chouteau Island to near Wood River	5.5	0.30
Glen Park to Chesley Island	4.2	0.41	Wood River to Alton	4.6	0.39

Discrepancies between right and left bank ordinary levels.

Field season.	Distance.	Locality where compared.	Difference.	Field season.	Distance.	Locality where compared.	Difference.
1888.	4	Elkins Landing	0.060	1889.	3	Ames Island	0.022
	3	Blackbird Island	0.168		2½	Perry Tow-head	0.008
	3½	Saladin Tow-head	0.105		3½	Below Calico Bar	0.029
	3	Thompson's Landing	0.061		2½	Head of Calico Bar	0.142
	4	Scudder Tow-head	0.187		4	Illinois Station	0.036
	3	Dickey Island	0.044		3	Head of Foster Island	0.105
	3½	Fountain Bluff	0.036		3	Montesano Springs	0.152
	3	Estelle's Landing	0.152		3	Foot of Widow Beard's Island	0.050
	3½	76 Landing	0.139		3½	Twin Hollows	0.029
	3	Wilkinson's Landing	0.074		3	Above Quarantine	0.029
	3	Price Landing	0.036		3½	Above Vulcan Iron Works	0.156
	3	Liberty Island	0.001		3	Head of Arsenal Island	0.006
	3	Foot of Crain's Island	0.046		3	L'Esperance street	0.197
	4	Cole's Mill	0.084		2	Eads Bridge	0.035
1889.	10	Head of Kaskaskia Cut-off	0.164		3	Merchants' Bridge	0.086
	1	Foot of Moro Island	0.133		1½	Foot of Gabaret Island	0.012
	4½	Head of Moro Island	0.115		3½	Head of Gabaret Island	0.015
	3	Above Little Rock Landing	0.134		4½	Head of Chouteau Island	0.031
	3	Head of Turkey Island	0.045		4½	Above mouth of Missouri River	0.007
	3	Bruce Island	0.025		6	Alton	0.005
	3	Brickey's Mill	0.137				
	3	Rush Island	0.133				

Discrepancies between precise and ordinary levels.

Field season.	Between P. B. M's.	Distance.	Discrepancies.	Observer.	Field season.	Between P. B. M's.	Distance.	Discrepancies.	Observer.
		Miles.					*Miles.*		
1888.	No. 64 and 65	21	—0.150	L. E. Ritter.	1889.	No. 25 and 23	8½	—0.086	J. H. Field.
	No. 45 and 44	3	+0.010	J. H. Field.		No. 23 and 22	2	—0.033	Do.
	No. 44 and 42	9	—0.107	Do.		No. 22 and 20	4	—0.055	Do.
	No. 42 and 41	7½	+0.018	Do.		No. 20 and 18	3	—0.033	Do.
	No. 41 and 39	6	+0.027	Do.		No. 18 and 17	2	+0.002	Do.
1889.	No. 38 and 35	7	+0.200	Do.		No. 17 and 16	2½	+0.132	Do.
	No. 35 and 34	11½	+0.002	Do.		No. 16 and 15	5	+0.006	Do.
	No. 34 and 33	3	—0.015	Do.		No. 15 and 14	3	+0.216	Do.
	No. 32 and 31	2½	—0.038	Do.		No. 14 and 12	9½	+0.085	Do.
	No. 31 and 30	4	+0.172	Do.		No. 12 and 11	4	—0.006	L. E. Ritter.
	No. 30 and 29	3	—0.031	Do.		No. 11 and 10	3	—0.029	Do.
	No. 29 and 27	10	—0.177	Do.		No. 10 and 8	4½	—0.194	Do.
	No. 27 and 25	6	.....	Do.					

The sum of these discrepancies is —0.058 foot for a distance of 102 miles.

Comparison of tertiary triangulation with chained sides.

1889.

Sides compared.	No. of triangles.	Tertiary lengths.	Measured lengths.	Discrepancies.
		Meters.		
▲ 19–▲ 21	20	1,243.8	1,242.6	1 in 1,036
▲ 35–▲ 37	19	1,250.6	1,249.1	1 in 834
▲ 47–▲ 49	15	1,298.7	1,296.7	1 in 649
▲ 65–▲ 67	22	1,3.5.5	1,376.6	1 in 1,251
▲ 91–▲ 93	28	1,235.69	1,235.64	1 in 24,713
▲ 107–▲ 109	17	1,318.9	1,312.8	1 in 1,194
▲ 139–▲ 141	45	1,118.6	1,118.9	1 in 3,729
▲ Alton–Church Spire	29	1,341.7	*1,341.8	1 in 13,418

* Secondary triangulation length.

REPORT OF CAPTAIN CHARLES F. POWELL, CORPS OF ENGINEERS, IN CHARGE OF GENERAL SERVICE.

ST. LOUIS, MO., *June* 8, 1890.

The movement of stone to the first and second districts, in progress at the end of last year, May 31, 1889, was completed during June and July; there were then delivered at—

Daniel's Point	yards..	8,499
Plum Point	do....	2,025
Helena	do....	8,208
Cairo (for Hickman)	do....	399
Total		19,131

All requisitions on the general service for stone having been filled, the towage fleet was laid up at Cairo.

The delivery of stone for the season, which had been commenced in March, was made with a small number of barges, and one tow-boat at one time, except that the *Mississippi* in returning from a Commission inspection trip brought up some empty barges. The stone was unloaded on the bank, except the last tow, by the district force and about as delivered. As the stage of water was very generally lower than average high water, the unloading was probably more costly than would ordinarily be during spring and early summer.

During the working season considerable repair was made to five barges, as they were in an unsafe condition, and new pillow-blocks and a boiler sheet were put on the tow-boat *Etheridge*.

As there appeared no probability of more call for stone, the fleets in the late fall were moved to Paducah for winter quarters, where they remain, except some barges left in the districts.

The twenty stone barges whose building was under contract at date of last report were completed; ten additional barges of the same kind were also built by the contractors for the general service upon purchase in open market. One old barge, 192, was rebuilt, by hired labor, from the bottom up; another old barge was cut down to the bottom gunwale with a view of rebuilding; old barge, 144, was lost while in service in the third district, and two old barges are in use for carrying houses of Commission survey boats. All this leaves thirty-one good stone barges, six good open-hold (fuel) barges, and forty-six old stone barges generally in poor condition, available for towage use after some repairs are made to the latter.

The tow-boat *Minnetonka* was hauled out, her bottom thoroughly repaired, and afterwards much repair made above the water-line. New cylinder timbers were put on the steamer *Vidette*, together with other new or repaired work; new cylinders are now being made for her, one cylinder having become wholly disabled and the other being weak. Some chalking, painting, and miscellaneous repairs or changes were made in the pieces of the fleet generally, being in the aggregate rather extensive.

The tow-boat *Etheridge*, belonging on the third district property return, but which has been with the general service for a few years, was called for by Captain Young during the flood and delivered to him at Memphis. The *Minnetonka* and *Mississippi*, also the Commission steamer *Patrol* and three barges, were kept in readiness for use at short notice during the flood.

The cost of maintaining and caring for the towage fleet during long periods of suspension of its work has been duly considered. With the view of arriving at some action in the matter, a searching inquiry has been made as to the actual cost of the general service stone and coal towage. The time before 1883 was a period of preparation and plant building, when not much stone towage was done, and its cost is complicated with that of the other work. The expenditure during the seven years ending December 31, 1889, was therefore taken as the bases for finding the unit cost; the amount was corrected by the unpaid obligations, the actual cost of each piece of service performed other than coal and stone towage, and by the value of plant on hand at the end of the period; then, considering the numbers of yard-miles of stone moved and equivalent of same of coal, the actual gross cost of 6.2 mills per yard-mile was obtained. During the 7-year period operations were conducted for thirty-eight months and suspended for forty-six months.

A similar method to that above was taken for finding the cost for each of the last two towage seasons, one being from October to December, 1888, a low-water season, and the other from March to July, 1889, a season of low high water, and the actual costs obtained, considering all expense of operation and current repairs, of 2.8 and 2.4 mills per yard-mile respectively, which show approximately the relative values of high and low-water towage; this, after allowing 13 cents per yard for the extra handling of the stone in high-water delivery, makes the cost of delivery of stone at Helena about equal for high and low water, and greater for low water for points below, and as much as 7 cents per yard greater for Wilson Point. It should be remarked that low-water stone delivery requires much more plant of the expensive kind and necessitates the risk of not supplying the stone as fast as needed during construction.

It is expected to subsequently submit the matter of the stone towage to the Commission with some recommendations in the premises.

Respectfully submitted,

CHAS. F. POWELL,
Captain, Corps of Engineers.

To the PRESIDENT OF THE MISSISSIPPI RIVER COMMISSION.

Approximate value of plant belonging to the United States and used in the general service, improving the Mississippi River from the Head of the Passes to the mouth of the Ohio River.

Class of property.	No.	Approximate value May 31, 1890.	Class of property.	No.	Approximate value May 31, 1890.
Steam-boat Mississippi	1	$45,000.00	Store-boat	1	$450.00
Steam-boat Minnetonka	1	30,000.00	Skiffs	7	100.00
Steam-boat Vidette	1	4,750.00	Sounding-boats	2	25.00
Barges, flush-deck, new	30	83,180.61	Calking-flat	1	20.00
Barges, flush deck	24	22,100.00	Office furniture	....	475.00
Barges, low deck	27	29,160.00			
Barges, open-hold	6	10,000.00	Total		225,260.61

Abstract of formal contracts in force.

No.	Name and address of contractor.	Contract.	
		Date.	Subject.
1	Madison Marine Railway Company, Madison, Ind.; per C. A. Korbly, secretary.	February 9, 1889	Building and delivering at Cairo, Ill., twenty wooden barges. Supplementary contract made extending time of completion twenty-five days. Contract completed.

Money statements, July 1, 1889, *to June* 30, 1890.

General service:		
Available July 1, 1889		$161,334.83
Refunded account payment for Hickman		3,288.83
Refunded account payment for Columbus		2,599.08
Refunded account payment for Helena		10,393.17
		177,615.91
Transferred to protection of levees, third district		20,000.00
		157,615.91
Expenditures apportioned to first district	$34,843.98	
Expenditures apportioned to Hickman	269.32	
Expenditures apportioned to second district	34,843.99	
Expenditures apportioned to Helena	10,393.17	
Expenditures apportioned to third district	34,844.00	
		115,194.46
In Treasury	39,978.82	
In hand	2,442.63	42,421.45
Illinois River to Ohio River, protection of the easterly bank of the Mississippi near Cairo:*		
Available July 1, 1889		8,600.00
First district—Plum Point Reach:		
Available July 1, 1889	254,944.10	
Applied by general service	34,843.98	
Deposit for overpayment	1.00	
Transferred from levees, Plum Point Reach	4,000.00	
		293,789.08
Transferred to protection of levees, second district	2,500.00	
Transferred to protection of levees, fourth district	21,000.00	
		23,500.00
		290,289.08
Expended		258,123.86
In Treasury	5,086.85	
In hand	7,078.37	
		12,155.22
Hickman, Kentucky:		
Available July 1, 1889	77,882.78	
Applied by general service	269.32	
		78,152.10
Refunded to general service	3,288.83	
Expended	26,215.51	29,504.34
In Treasury	47,461.17	
In hand	1,186.59	
		48,647.76

* Includes only funds under act of July 5, 1884.

Columbus, Kentucky:		
Available July 1, 1889		$33,478.21
Refunded to general service	$2,599.08	
Expended	17,862.97	20,462.05
In Treasury	6,150.72	
In hand	6,865.24	
		13,016.16
Maintenance of existing works:		
Available July 1, 1889		27,250.00
Transferred to protection of levees, third district		27,250.00
Gauges:		
Available July 1, 1889		1,651.50
Expended		720.00
In Treasury	900.00	
In hand	31.50	
		931.50
Observations and discharges:		
Available July 1, 1889		370.92
Expended		370.92
Surveys, examinations, and inspections:		
Available July 1, 1889		2,744.91
Expended		903.46
In Treasury	1,000.00	
In hand	841.45	
		1,841.45
Care of plant first and second districts:		
Available July 1, 1889		60,000.00
Expended		39,547.85
In Treasury	14,000.00	
In hand	6,452.15	
		20,452.15
Surveys first and second districts:		
Available July 1, 1889		1,815.80
Expended		560.50
In Treasury	1,000.00	
In hand	255.30	
		1,255.30
Second district—Memphis Reach:		
Available July 1, 1889	37,523.06	
Applied by general service	34,843.99	
	72,367.05	
Transferred to protection of levees, fourth district	20,000.00	52,367.05
Expended		36,188.38
In Treasury	13,500.00	
In hand	2,678.67	
		16,178.67
Memphis Harbor:		
Available July 1, 1889		14,833.75
Expended		9,214.01
In Treasury	4,750.00	
In hand	869.74	
		5,619.74

Helena:		
Available July 1, 1889	$71,174.09	
Applied by general service	10,393.17	
		$81,567.26
Refunded to general service	10,393.17	
Expended	71,171.29	
		81,564.46
In hand		2.80
Gauges:		
Available July 1, 1889		792.50
Expended		510.00
In Treasury	100.00	
In hand	182.50	
		282.50
Observations and discharges:		
Available July 1, 1889		522.07
Expended		520.00
In hand		2.07
Surveys, examinations, and inspections:		
Available July 1, 1889		2,913.96
Expended		1,338.90
In Treasury	1,000.00	
In hand	575.06	
		1,575.06
Third district—Lake Providence Reach:		
Available July 1, 1889	455,566.84	
Applied by general service	34,844.00	
		490,410.84
Transferred to protection of levees, third district	55,000.00	
Transferred to protection of levees, fourth district	20,000.00	
Transferred to protection of levees, Tensas Front, fourth district	25,000.00	
		100,000.00
		380,410.84
Expended		383,884.18
In hand		6,526.66
Vicksburg Harbor:		
Available July 1, 1889	101,098.49	
Deposit for overpayment	.25	
		101,098.74
Expended		63,792.99
In Treasury	*15,000.00	
In hand	22,305.75	
		37,305.75
Vicksburg Harbor—Delta Point:		
Available July 1, 1889		156.58
Expended		0.00
In hand		156.58
Greenville, Mississippi:		
Available July 1, 1889		33,204.13
Expended		29,721.65
In hand		3,482.48

*This amount is reserved for such repairs and extension of the Delta Point revetment as may prove to be necessary.

Lake Bolivar Front:		
Available July 1, 1889		$46,605.52
Transferred to surveys, examinations, and inspections, third district	$4,000.00	
Transferred to surveys, examinations, and inspections, fourth district	3,000.00	
Transferred to protection of levees, fourth district	3,000.00	
Transferred to protection of levees, third district	5,000.00	
		15,000.00
		31,605.52
Expended		11,315.80
In Treasury	20,000.00	
In hand	289.72	
		20,289.72
Gauges:		
Available July 1, 1889		1,229.65
Expended		730.75
In Treasury	300.00	
In hand	198.90	
		498.90
Observations and discharges:		
Available July 1, 1889		82.38
Expended		82.38
Surveys, examinations, and inspections:		
Available July 1, 1889	1,970.63	
Transferred from levees, second Mississippi district	1,535.68	
Transferred from levees, Ben Lomond Hoop	613.78	
Transferred from levees, Lake Bolivar Front	4,000.00	
		8,120.09
Expended		7,057.83
In hand		62.26
Fourth district—New Orleans Harbor:		
Available July 1, 1889	127,041.62	
Deposit for overpayment	.04	
		127,041.66
Expended		78,522.04
In Treasury	45,000.00	
In hand	3,519.62	
		48,519.62
Red and Atchafalaya rivers:		
Available July 1, 1889	88,560.13	
Deposit for overpayment	.10	
		88,560.23
Expended		64,828.60
In Treasury	15,000.00	
In hand	8,731.63	
		23,731.63
Natchez and Vidalia:		
Available July 1, 1889		700.65
Expended		25.00
In hand		675.65

Gauges:		
Available July 1, 1889		$1,125.22
Expended		725.20
In hand		400.02
Observations and discharges:		
Available July 1, 1889		2,460.41
Expended		2,460.41
Surveys, examinations, and inspections:		
Available July 1, 1889	$594.44	
Transferred from Lake Bolivar Front	3,000.00	
		3,594.44
Expended		2,087.03
In hand		1,507.41
Levees (first district):		
Plum Point:		
Available July 1, 1889		19,894.60
Transferred to protection of levees, fourth district	15,000.00	
Transferred to Plum Point Reach	4,000.00	
		19,000.00
		894.60
Expended		818.63
In hand		76.97
Survey of St. Francis Front:		
Available July 1, 1889		471.83
Expended		471.83
Levees (second district):		
White River Front:		
Available July 1, 1889		3,954.35
In Treasury	2,500.00	
In hand	1,454.35	
		3,954.35
First Mississippi district:		
Available July 1, 1889		7,677.84
Expended		7,167.76
In hand		510.08
Protection of levees:		
Available July 1, 1889	5,000.00	
Transferred from Plum Point Reach	2,500.00	
		7,500.00
Expended		1,595.55
In Treasury	5,000.00	
In hand	904.45	
		5,904.45
Levees (third district):		
Tensas Front (Ark.):		
Available July 1, 1889		1,936.46
Expended		1,936.46
Yazoo Front, Ben Lomond Hoop:		
Available July 1, 1889		613.78
Transferred to surveys, examinations, and inspections		613.78

Second Mississippi district:		
Available July 1, 1889		$1,649.32
Expended	$113.64	
Transferred to surveys, examinations, and inspections	1,535.68	
		1,649.32
Protection of levees:		
Available July 1, 1889	23,701.57	
Transferred from general service	20,000.00	
Transferred from Lake Providence Reach	55,000.00	
Transferred from maintenance of existing works	27,250.00	
Transferred from Lake Bolivar Front	5,000.00	
Deposit for overpayment	3.00	
		130,954.57
Expended		130,207.14
In hand		747.43
Levees (fourth district):		
Tensas Front:		
Available July 1, 1889	87,199.14	
Transferred to protection of levees, fourth district	10,000.00	
		77,199.14
Expended		48,081.72
In hand		29,117.42
Protection of levees, Tensas Front:		
Available July 1, 1889	9,371.77	
Transferred from protection of levees, fourth district	10,000.00	
		19,371.77
Expended		19,371.77
Protection of levees:		
Available July 1, 1889	10,000.00	
Transferred to protection of levees, Tensas Front	10,000.00	
Transferred from Memphis Reach	20,000.00	
Transferred from Lake Providence Reach	45,000.00	
Transferred from levees, Tensas front, fourth district	10,000.00	
Transferred from levees, Plum Point Reach	15,000.00	
Transferred from Plum Point Reach	21,000.00	
Transferred from Lake Bolivar Front	3,000.00	
		114,000.00
Expended		95,839.87
In hand		18,160.13
Levees, total:		
Available July 1, 1889		171,470.66
Transferred to surveys, examinations, and inspections, Third district	2,149.46	
Transferred to Plum Point Reach	4,000.00	
		6,149.46
		165,321.20
Transferred from Lake Providence Reach		100,000.00
Transferred from general service		20,000.00
Transferred from Memphis Reach		20,000.00
Transferred from Plum Point Reach		23,500.00
Transferred from maintenance of existing works		27,250.00
Transferred from Lake Bolivar Front		8,000.00
Deposit for overpayment		3.00
		364,074.20
Expended		305,604.37
In Treasury	7,500.00	
In hand	50,969.83	
		58,469.83

Consolidated statement, March 3, 1881, to June 30, 1890.

Act of March 3, 1881		$1,000,000.00
Act of August 2, 1882		4,123,000.00
Act of January 19, 1884		1,000,000.00
Act of July 5, 1884, less $5,000 transferred to snag-boat service		2,065,000.00
Act of August 5, 1886, less $5,942.60 for expenses, office Chief of Engineers		1,994,057.40
Act of August 11, 1888, less $4,289 for expenses, office Chief of Engineers		2,840,711.00
Total specific appropriations		13,022,768.40
Balances from former appropriations applied to works below Cairo under act of August 2, 1882, less $123.42 reverted to Treasury	$272,504.96	
Same for work above Cairo, under act of July 5, 1884	22,632.53	
Total balances		295,137.49
Received from sales, loss of property, and deposits		675.88
Total available		13,318,581.77
Expended to June 30, 1890:		
River works	$9,759,217.89	
Levees	3,183,745.54	
		12,942,963.43
Balance July 1, 1890		375,618.34

Detailed statement, March 3, 1881, to June 30, 1890.

Districts.	Balances.	Appropriations and allotments.	Applied by general service.	From sales, etc.	Total available.	Expended.	In Treasury.	In hand.	Total balances.
Des Moines Rapids to Illinois River	$12,663.38	$195,000.00	.....	$145.14	$207,808.52	$207,808.52	.....	.....	.....
Illinois River to Ohio River	9,969.15	470,000.00	.....	126.60	480,095.75	480,095.75	.....	.....	.....
Protection near Cairo	.....	50,000.00	.....	10.85	50,010.85	41,410.85	.....	$8,600.00	$8,600.00
Total	9,969.15	520,000.00	.....	137.45	530,106.60	521,506.60	.....	8,600.00	8,600.00
Survey St. Francis Front	.....	9,873.11	.....	.....	9,873.11	9,873.11	.....	.....	.....
New Madrid Reach	.....	200,721.86	$9,640.05	2.83	210,364.74	210,364.74	.....	.....	.....
Plum Point Reach	.....	2,735,321.18	285,448.95	106.70	3,020,876.83	3,008,711.61	$5,086.85	7,078.37	12,165.22
Hickman, Ky	.....	85,461.17	3,288.83	.....	88,750.00	40,102.24	47,461.17	1,186.59	48,647.76
Columbus, Ky	.....	41,150.92	2,599.08	.....	43,750.00	30,733.84	6,150.92	6,865.24	13,016.16
Gauges	.....	2,500.00	.....	.....	2,000.00	1,068.50	900.00	31.50	931.50
Observations and discharges	.....	3,000.00	.....	.....	3,000.00	3,000.00	.....	.....	.....
Surveys, examinations, and inspections	.....	3,000.00	.....	.....	3,000.00	1,158.55	1,000.00	841.45	1,841.45
Levees, Plum Point	.....	156,000.00	.....	.....	156,000.00	155,924.03	.....	75.97	75.97
Total First District	.....	3,236,528.24	300,976.91	109.53	3,537,614.68	3,460,936.62	60,598.94	16,079.12	76,678.06
Survey, St. Francis Front	.....	4,000.00	.....	.....	4,000.00	4,000.00	.....	.....	.....
Helena Reach	.....	8,000.00	.....	.....	8,000.00	8,000.00	.....	.....	.....
Levees, Long Lake	.....	15,000.00	.....	.....	15,000.00	15,000.00	.....	.....	.....
Yazoo Front	.....	140,950.00	.....	.....	140,950.00	140,950.00	.....	.....	.....
White River Front	.....	75,000.00	.....	.....	75,000.00	71,045.65	2,500.00	1,454.35	3,954.35
First Mississippi district	.....	50,000.00	.....	.....	50,000.00	49,489.92	.....	510.08	510.08
Yazoo, Miss., Delta	.....	100,000.00	.....	.....	100,000.00	100,000.00	.....	.....	.....
Protection of levees	.....	7,500.00	.....	.....	7,500.00	1,595.55	5,000.00	904.45	5,904.45
Memphis Harbor	.....	256,750.00	.....	22.80	256,772.80	251,153.06	4,750.00	869.74	5,619.74
Reach	.....	160,000.00	50,821.51	.....	210,821.51	194,642.84	13,500.90	2,678.67	16,178.67
Harbor and reach	.....	431,792.38	138,282.94	27.14	570,052.46	570,052.46	.....	.....	.....
Helena	.....	64,606.83	10,393.17	.....	75,000.00	74,997.20	.....	2.80	2.80
Gauges	.....	1,000.00	.....	.....	1,000.00	717.50	100.00	182.50	282.50
Observations and discharges	.....	3,000.00	.....	.....	3,000.00	2,997.93	.....	2.07	2.07
Surveys, examinations, and inspections	.....	3,000.00	.....	.....	3,000.00	1,424.94	1,000.00	575.06	1,575.06
Total second district	.....	1,320,599.21	199,447.62	49.94	1,520,096.77	1,486,067.05	26,850.00	7,179.72	34,029.72
Care of plant, first and second districts	.....	85,005.99	.....	.....	85,005.99	64,553.84	14,000.00	6,452.15	20,452.15
Surveys, first and second districts	.....	10,000.00	.....	.....	10,000.00	8,744.70	1,000.00	255.30	1,255.30

Unleveed fronts		1,000.00			1,000.00	1,000.00			
Choctaw Reach		2,679.86			2,679.86	2,679.86			
Levees, Opossum Fork		120,000.00			120,000.00	120,000.00			
Yazoo Front		364,878.95			364,878.95	364,878.95			
Yazoo Front (Ben Lomond)		11,386.22			11,385.22	11,386.22			
Yazoo Front (Hughes Break)		6,849.69			6,849.69	6,849.69			
Tensas Front		566,723.00			566,723.00	566,723.00			
Tensas Front, Arkansas		179,920.86		.08	179,920.04	179,920.94			
Second Mississippi district		58,464.32			58,464.32	58,464.32			
Protection of levees		155,307.00		3.00	155,310.00	154,562.57		747.43	747.43
Existing works		25,000.00			25,000.00	25,000.00			
Greenville, Miss		100,499.02	30,712.79		131,211.81	127,729.33		3,482.48	3,482.48
Repairs to floating plant		30,000.00			30,000.00	30,000.00			
Vicksburg Harbor, dredging and dam		284,312.12		25	284,312.37	247,006.62	*15,000.00	22,305.75	37,305.75
Delta Point	25,770.13	107,736.46			133,506.59	133,350.01		156.58	156.58
Lake Providence Reach		2,647,876.84	238,728.35	218.95	2,886,823.64	2,880,296.98		6,526.66	6,526.66
Care of plant and surveys		24,360.00			24,360.00	24,360.00			
Lake Bolivar Front		131,000.00	8,028.19	.04	143,028.23	122,738.51	20,000.00	289.72	20,289.72
Gauges		1,600.00			1,600.00	1,101.10	300.00	198.90	498.90
Observations and discharges		3,000.00			3,000.00	3,000.00			
Surveys, examinations, and inspections		10,149.46			10,149.46	9,087.20	1,000.00	62.26	1,062.26
Total third district	25,770.13	4,839,243.30	277,469.33	222.32	5,142,705.08	5,072,635.30	36,300.00	33,769.78	70,069.78
Survey Cubitt's Gap		137.14			137.14	137.14			
Unleveed fronts		1,000.00			1,000.00	1,000.00			
Observations at Carrollton		3,000.00			3,000.00	3,000.00			
Bonnet Carre Crevasse		15,000.00			15,000.00	15,000.00			
Natchez and Vidalia harbors	8,252.04				8,252.04	7,576.39		675.65	675.65
New Orleans Harbor	147,670.39	281,295.86	1,527.61	.04	430,493.90	381,974.28	45,000.00	3,519.62	48,519.62
Mouth of Red River	90,812.40	38,405.00			129,217.40	129,217.40			
Red and Atchafalaya rivers		437,500.00		.20	437,500.20	413,768.57	15,000.00	8,731.63	23,731.63
Gauges		2,000.00			2,000.00	1,599.98		400.02	400.02
Observations and discharges		9,000.00			9,000.00	9,000.00			
Levees, Tensas Front		889,422.00			889,422.00	860,304.58		29,117.42	29,117.42
Atchafalaya Front		176,800.00			176,800.00	176,800.00			
Protection of levees, Tensas Front		23,000.00			23,000.00	23,000.00			
levees		114,000.00			114,000.00	95,839.87		18,160.13	18,160.13
Surveys, examinations, and inspections		4,000.00			4,000.00	2,492.59		1,507.41	1,507.41
Total fourth district	246,734.83	1,994,560.00	1,527.61	.24	2,242,822.68	2,120,710.80	60,000.00	62,111.88	122,111.88
General service		42,410.19		11.26	42,421.45		39,978.82	2,442.63	42,421.45
Grand totals	295,137.49	12,243,346.93	779,421.47	675.88	13,318,581.77	12,942,963.43	238,727.76	136,890.58	375,618.34

* This amount is reserved for such repairs and extension of the Delta Point revetment as may prove to be necessary.

APPENDIX F.

REPORT OF CAPTAIN S. S. LEACH, CORPS OF ENGINEERS, UPON OPERATIONS IN TH FIRST DISTRICT.

UNITED STATES ENGINEER OFFICE,
Memphis, Tenn., June 1, 1890.

GENERAL: I have the honor to submit the following report of operations in the fir district under the appropriation for improving Mississippi River, acts of August 1 1888, and prior dates, from May 31, 1889, to May 31, 1890.

The part of the river to which this report relates, known as the first district, exten from Cairo to the foot of Island 40, a distance of 220 miles. Work has been carri on at various localities named in the acts or designated by the Commission. They a noted in geographical order beginning at the upper end of the district.

COLUMBUS, KENTUCKY.

The act of August 5, 1886, appropriated $18,750 for improving the river at this poin A further appropriation of $25,000 in the act of August 11, 1888, made a total of $43,7 available.

A project for the expenditure of this sum was submitted and was approved by t Commission November 28, 1888, and by the Secretary of War January 23, 1889. provided for a revetment to consist of five spur-dikes of brush and stone so dispos as to cover the part of the bank threatened by caving, in length about 2,200 feet.

In the detail plan drawn up in pursuance of the approved project, each dike co sisted of a floor or foundation mattress 200 feet long up and down stream, and e tending from the low-water line 300 feet out into the river. This mattress was co tinued up the bank on a prepared slope of three horizontal to one vertical, as near the top as possible. It could not go entirely to the top in all cases, on account of t proximity of a levee. On this mattress was laid a single brush-crib, 28 feet wide a 8 feet high, extending from the upper edge of the mattress to a point 240 feet beyo low-water mark. The crib was placed with its center line 12 feet above the cent line of the mattress.

At the beginning of the fiscal year the stone for this work had been delivered a stored on the bank. During the last days of October, 1889, two pile-drivers we sent to Columbus from the plant working at Hickman, and the grading and drivi of mooring and fender-piles were begun. By November 6 work was completed Hickman and the entire plant transferred to Columbus. Rapidly rising river wi heavy drift made it impossible to begin the mattress construction, and these adve conditions continued until December 7, when the plant was swung into position a weaving begun. Thus the month in which it was hoped to do two-thirds of the wo became a month of lost time.

Substantial progress in the execution of the project dates from December 7, 18 The conditions were at no time favorable, as the river stood at 17 to 20 feet abo low water, the current was rapid, considerable drift appeared from time to time, a the weather was stormy to an unusual degree. In one of his bi-monthly reports, t assistant in charge noted that there had been but four fair days during the fifte By January 4, 1890, a little less than a month, the floor mats of Nos. 5, 4, and 3, i cluding shore connections, and the cribs of No. 4, were completed. The subaqueo crib of No. 5, or part below low water, was also done. At this time the river w rising rapidly, water for a bank-full stage was in sight, and the approach of t spring flood was plainly indicated. It was therefore decided to close for the seaso but before doing so a partial foundation mattress, extending from top of bank to 1 feet beyond low water, was built and sunk on the site of No. 2 dike, to preserve t grade, which had been completed to prevent erosion on the site of the dike. T shore-crib of No. 5 was also built afloat and sunk in place, the water being then ne the top of the bank. This work was completed, as well as the housing of lines a tools, by the 18th of January, and on the 20th the plant was moved to laying-u quarters at Island 30.

In less than a month of most unfavorable conditions both of river and weathe over half of the project was accomplished, a very favorable showing, made possib only by the fact that the force was thoroughly trained and fresh from work of great intrinsic difficulty.

Operations can be resumed in time to have the work completed and the pla released before the date at which the next appropriation will become available.

An itemized statement of the expenditures is herewith, as well as the usual fisc statements. The balance on hand is sufficient to complete the project, and the wo

vill, if successful, protect the water-front of Columbus from further recession. No urther estimate is submitted.

A map of the locality, with a graphic exhibit of the work done and proposed, accompanies this report.

HICKMAN, KENTUCKY.

The act of August 5, 1886, contained a provision of $18,750 for work at this point, o which was added $70,000 by the act of August 11, 1888, making a total of $88,750 vailable at the latter date. A project for the work was approved by the Commission November 28, 1888, and by the Secretary of War December 19, 1888. In May, 889, after a visit of inspection to the locality, the Commission modified the project, nd in its final shape it provided for 1,000 feet of standard continuous revetment, xtending from the lower side of the indurated clay point which projects into the iver to a point near the old railroad depot.

The line to be protected had approximately a crescent shape, the high steep bluff ouching the water-line at the upper end, succeeded by a shelf or terrace of lower levation near the middle and an alluvial bank somewhat below the level of high vater at the lower end. To meet these conditions the upper bank work was started t 25 feet width at the upper end, bringing it about 10 feet above low water, and vas gradually widened, its upper edge increasing in elevation until, at a point somevhat above the middle, it attained a width of 90 feet, with its upper edge 10 feet elow the high water of 1882.

Hydraulic grading began on September 2, 1889. From the outset this part of the ork proved to be unusually difficult. At the upper end the material to be removed eing of the bluff formation was unusually hard and, in places, the large quantity of vater necessary to dislodge it caused a serious sloughing near the water surface, so hat jet grading had to be abandoned and a considerable quantity of earth removed vith shovels and sluices. Near the middle of the work, for a distance of about 100 eet, there appeared a stratum of greasy clay, inclined toward the river and outropping 8 feet above the grade. On this stratum the superincumbent earth slid oward the river at the rate of 2½ feet a day, the projecting portion breaking off at ntervals and falling upon the grade. After much time and labor had been spent in ttempting to maintain a clear grade, it was decided to clean it off quickly, just after fall of earth, place the fastenings and lay the upper part of the shore-work and then llow the earth to fall on top of it. Near the lower end of the revetment some isoated piles of riprap, deposited years ago by the railroad company, were encountered, nd it was thought necessary to remove the parts protruding above the adopted rade. At no part of the bank covered was the grading of the usual character. The esult is seen in the cost of grading as shown in the exhibit, which is two and a half o three times greater than usual.

On account of the projection of the point at which the mooring barges were to rest, ne rapid recession of the bank above, and the width of the proposed mattress (300 eet), it was not deemed prudent to depend upon the method of fastening heretofore mployed, by extending lines from the mooring barges and mat-head directly to shore, s the lead would have been very oblique and the length of lines very great. A new ystem was adopted, depending on two large Chinese anchors. These held two barges n position, and from the barges the head and shackle lines were worked. The prepration of this anchorage and the grading and partial construction of shore-work occupied a force of the usual strength until October 4, when the weaving of the subqueous mattress was begun. It was completed on the 21st and sunk on the 24th of he same month. It was 300 feet wide and made continuous with the shore-work for distance of 750 feet, beyond which the outer edge was continued on the same line nd two offsets made on the inside, which were afterward covered with connecting ats. This design was necessary, as it was not feasible to build so wide a mat around short a curve. The two connecting mats, the remaining shore-work, and the recovry of the anchors and cables were accomplished by November 6, and the work at Hickman was closed on that day.

An itemized statement of the expenditures and other financial exhibits are herewith. A map of the locality showing the extent and position of the work is also ubmitted.

The statement shows the work to have cost $24.10 per foot of bank protected. Considering the unusual cost of grading, the width of the mat, the cost of providing the nchorage, and the small amount of work involved, this figure compares very favorably with previous work.

No inspection of the work has been made since the subsidence of the late flood, but rivate advices from Hickman represent the work as having been entirely successful, displacement of any part of it having been observed.

REPORT

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:a Point Revetment.—A short piece of revetment was projected here to check caving, which threatened the stability of the three crossings immediately below. e time the work was begun the portion of bank needing protection was about feet long, two in approximately straight lines of equal length, meeting in a very e angle. The lower half had the desired trend, its prolongation being almost ly in the line of the crossing. It was decided to protect this part and postpone ipper half until it should have caved back to the same line with the protected

th this view a river mat 150 feet wide was begun on the 1st of July. It was leted to a length of 800 feet and sunk on the 12th. As caving was active at the the work was begun, the river-mat was laid in advance of the grading. The r was begun as soon as the mat was down and the connecting mats and shore- were completed on the 9th of August.

nieFs Point Revetment.—The project approved for this locality contemplates the truction of a continuous revetment from the extreme point up, an estimated dis- e of 5,000 feet, with a probable cost of $100,000. The delivery of stone began in latter part of May, 1889, and by the end of the last fiscal year it was mostly ed on the bank.

n the 23d of July grading was begun at the lower end, and on the same day a diver h a blasting equipment began the removal of snags, which was completed on the of August. The latter days of the month were occupied in the preliminary work lressing the slope and storing brush on it, and on the 31st the weaving plant was in operation. The plan adopted was to build the revetment in five sections, be- ning at the lower end. The method used was that of lateral continuity, in which shore revetment is built wholly or in part and connected to the river-mat before xing the latter, as already described in connection with work on Sections A and E, tcher's Bend. The river-mat was 200 feet wide, but was held out by a line of pil- so as to give a protection equal to that of a 225-foot mat. This method was pted on account of the limited length of mooring and weaving barges avail- e. The first mattress, 1,100 feet long, was sunk on the 19th of September, and the ond, begun on the 21st, was sunk on the 2d of October. The third section was be- on the 5th and sunk on the 19th of October, and the fourth section begun on the h. Early in November the river began to rise, with much drift running, and at same time work was retarded by local rains, causing loss of time and shortening brush supply. On the 9th of October, when 800 feet of the fourth section was npleted, the condition of the mooring barges became somewhat critical and it was ided to sink the upper part. The section was successfully completed and the rest it sunk on the 11th.

By this time the water-surface had risen almost to the upper edge of the 4,000 feet partial shore-work, and as the reports from above indicated a considerable further se, the entire force was set to work to complete the shore-work to the top of the nk. The rapid rise and unfavorable weather continued, and it was with great dif- ulty that the work was kept ahead of the water, the force being worked on Sun- ys and on several days of steady rain. By the end of November this work had en completed, the condition of affairs at that date being 4,300 feet of completed ork, 1,100 feet of finished grade, the river high and rising, and work temporarily spended. As the river fell some caving took place along the grade of Section 5, hich was also injured throughout its length by wave-wash. Considerable work was quired to restore it.

Weaving could not be resumed until December 19, when the fifth and last section as begun. It was completed and sunk on the 2d of January, 1890. The work had een extended up-stream to reach a deep pocket in the original bank-line, where a eturn could be carried back to protect the head of the work from being flanked. A hort mat was built to carry the under-water protection around the flank, and the pper bank was graded to a cone, on which the upper work was laid. At the head of he first or down-stream section there was also a pocket, around which the grade ould not well be carried. The river mat was made continuous across its chord, an rregularly-shaped mat was made and sunk on its floor, and a protection was carried up around its sides on a sand-beach or natural grade to about mid-stage, On the lower flank a conical return was made, as at the head of the work just described. The upper flank was graded and left without protection. These constructions and the completion of shore-work of Section 5 occupied the time until January 14, when the plant was withdrawn and the force disbanded.

The work as completed forms a continuous protection 5,300 feet in length. It is on an extreme point which was rapidly caving and has an unprotected bend, heretofore caving, above it. It is designed to form a fixed guiding line at all stages to deflect the current over the bar, and will greatly contribute to the stability of the channel, more so than the same amount of work in any other place could possibly do. As it must from its situation receive continuously the full impact of the stream, it was made somewhat heavier than usual, and especial attention was given to details of

construction, involving at times a slightly greater cost. The cost was further increased by the rehandling of stone, which was delivered before the work began, piled on the bank and again wheeled partly on barges and partly on the mat and shore-work direct. The total field cost was $19.05 per foot of bank protected.

Elmot and Island, thirty dikes.— The design and purpose of these dikes, the construction of the shore protections, and the greater part of the foot-mats for them, and the necessary postponement of the pile-driving on account of the stage of water not having been sufficient to float out the piles, were noted in the last report.

In the latter half of June, 1889, the construction of foot-mats was resumed and almost completed when the falling river necessitated a withdrawal of the plant. On January 30, 1890, a sufficient stage having been reached to enable the contractor to float out the piles, operations were again resumed, the completion of the foot-mats receiving first attention. Actual pile-driving began on February 3 and continued until the middle of March, when, the river being at extreme flood stage and all work which could be advantageously done at that stage being accomplished, operations were temporarily suspended. They were resumed on April 17, and at the date of this report the dikes are within a few days of completion. Data as to cost must be deferred for a future report. The locations of the dikes are shown on the map of the reach herewith.

The routine surveys on the reach, having for their object a connected history of the improved channel, have continued. The principal results are collected in an appended table at depths and velocities at different dates. The party has obtained other important data, both here and elsewhere.

None of the works have been injured during the year. As previously reported, the completion of the Fletcher's Bend revetment has been delayed to await the final destruction of a detached piece of old work projecting into the river and the recession of the bank to a fair line. During the last working season a deficit of stone occurred and some was removed from this old work, thus hastening its destruction. During the late flood it finally disappeared, and at the date of this writing the shore-line has the position shown on the map. The project can be completed at any time when funds are available.

The Plum Point Reach was selected for improvement because it was known to be the most difficult piece of river below Cairo and with the idea that a favorable result at this point would be a crucial test and would establish beyond peradventure the success of the system under which it had been achieved. Work has been in progress with some interruptions from lack of funds for eight years. The three features of the Commission's plan—protection of banks, contraction of channel-way, and confinement of floods by levees—have nearly reached the development contemplated at the outset. The question, "What is the result?" will surely be asked and will be anticipated. From the stand-point of practical navigation the results may be summed up in the statement that as an obstruction to navigation the Plum Point Reach is a thing of the past. For the past three years the depth at extreme low water has not fallen below 9 feet and at higher stages the depths have been proportionately greater. The depths are practically double those which obtained at the same places before the improvement was begun. The thalweg now remains unchanged during all stages, from extreme low water to extreme flood. The former shoal and shifting crossings have become so permanent both in depth and direction that pilots seldom sound them or take any note of them in their reports.

While these facts are highly gratifying they do not present the results of the work in their largest and most important aspect. That the control of the stream at all stages will cause a permanent increase in the size of the bed and in its discharging capacity is the fundamental principle upon which the improvement was projected and by which it can alone be fully justified. That such increase has taken place in the Plum Point Reach there is ample evidence. It is apparent to the most casual observation of one familiar with the low-water aspect of the reach in 1880 and 1890. It is shown unmistakably by a comparison of the surveys taken at frequent intervals during the progress of the work. But it appears with the greatest clearness and certainty by a comparison of low-water slopes, since that quantity is a function of all the variables which enter the problem and is perhaps the most sensitive index which the river presents of the ultimate effect of changes going on in its bed.

In a diagram submitted herewith will be found the low-water profiles of 1879, 1886–'87, and 1889. The first represents conditions prevailing before the improvement was undertaken while the others represent those of the improved river. The waters of 1879, 1887, and 1889 were, as seen by their elevations at Fulton, a point below the influence of the works, nearly of the same volume. That of 1886 was greater in volume but small enough to feel and manifest the effect of changes in the bed. If it had fallen as low as the others at Fulton it would evidently have corresponded closely with 1887 and 1889 above. These profiles show, as the result of the control of the stream by the works and in addition to the deepening of the channel for navigation, a lowering of

1 to 3 feet in the surface of low water of equal volume, so distributed as to produce a marked decrease of slope, which is an unfailing sign of an enlarged channel.

What has been accomplished here can safely be promised elsewhere and with much less expenditure of time and money. Not only must other points be intrinsically less difficult than this, as before noted, but the knowledge of principles gained and the improvements of methods developed in this undertaking would make it easy to do it over again in half the time and at two-thirds the cost.

There has been a marked increase in the river tonnage during the past year. The records containing information are so kept that a correct estimate of traffic can not well be made except for the entire river below Cairo as a unit. No new lines have been established during the year in the first district, but some of the existing lines have added new boats and have had their entire equipments more fully employed than ever before. Based on unofficial data and an extensive personal knowledge of the traffic in the district, the amount of 3,500,000 tons is confidently stated as a minimum for the total traffic of all kinds passing through the whole or a part of the first district during the twelve months covered by this report. There will be found herewith a tabulated statement of the shipments from the port of Cairo, the principal one in the district, kindly furnished by Mr. E. W. Halliday, of that place.

There are submitted herewith itemized statements of expenditure, a map of the Plum Point Reach, showing the location of the various works, and a series of photographs illustrating the methods of construction.

There are also submitted consolidated statements of expenditures for the entire district, classified as to the manner of making them as required by law, a general balance-sheet, and a table of values of plant.

Very respectfully, your obedient servant,

SMITH S. LEACH,
Captain of Engineers.

General C. B. COMSTOCK,
President Mississippi River Commission.

APPROPRIATION FOR IMPROVING MISSISSIPPI RIVER, FIRST DISTRICT.

Money statement.

July 1, 1889, balance available		$270,601.80
June 5, 1889, amounts allotted by Mississippi River Commission to Plum Point Reach, viz:		
From unallotted reserve	$129,586.85	
From general service allotment	19,000.00	
November 30, 1889, amount refunded on account of overpayment	1.00	
		148,587.85
Total		418,589.65
Amounts transferred as follows:		
March 15, 1890, from levees, Plum Point Reach, to protection of levees, fourth district	19,000.00	
March 22, 1890, from Plum Point Reach to protection of levees, second district	2,500.00	
March 31, 1890, from maintenance of existing works to protection of levees, third district	27,250.00	
April 22, 1890, from Plum Point Reach to protection of levees, fourth district	17,000.00	
June 30, 1890, amount expended from June 1, 1889, to date, exclusive of liabilities:		
Outstanding June 1, 1889	276,306.14	
June 30, 1890, amount expended by general service, as follows:		
On account Hickman, Ky	3,288.83	
On account Columbus, Ky	2,599.08	
Outstanding liabilities	4,096.75	
		352,040.80
June 30, 1890, balance available		66,548.85
Amount that can be profitably expended in fiscal year ending June 30, 1892		1,000,000.00

Submitted in compliance with requirements of sections 2 of river and harbor acts of 1866 and 1867.

General balance sheet.

PLUM POINT REACH.

1889.			1890.		
June 1	To balance, including estimated liabilities	$114,313.70	Mar. 22	By amount transferred to protection of levees, second district	$2,500.00
June 5	To amount allotted by Mississippi River Commission	148,586.85	Apr. 22	By amount transferred to protection of levees, fourth district	17,000.00
Nov. 30	To amount refunded on account of overpayment	1.00	June 30	By amount expended from June 1, 1889, to date	231,236.33
			June 30	By liabilities	3,776.75
			June 30	By balance	8,388.47
		262,910.55			262,901.55

MAINTENANCE OF EXISTING WORKS, FIRST DISTRICT.

1889.			1890.		
June 1	To balance	$27,250.00	Mar. 31	By amount transferred to protection of levees, third district	$27,250.00

LEVEES, PLUM POINT REACH.

1889.			1890.		
June 1	To balance	$19,894.60	Mar. 15	By amount transferred to protection of levees, fourth district	$19,000.00
			June 30	By amount expended to date	818.63
			June 30	By balance	75.97
		19,894.60			19,894.60

SURVEY OF ST. FRANCIS FRONT.

1889.			1890.		
June 1	To balance, including estimated liabilities	$643.56	June 30	By amount expended to date	$643.56

OBSERVATIONS AND DISCHARGES, FIRST DISTRICT.

1889.			1890.		
June 1	To balance, including estimated liabilities	$500.92	June 30	By amount expended to date	$500.92

GAUGES, FIRST DISTRICT.

1889.			1890.		
June 1	To balance, including estimated liabilities	$1,651.50	June 30	By amount expended to date	$720.00
			June 30	By liabilities	180.00
			June 30	By balance	751.50
		1,651.50			1,651.50

General balance sheet—Continued.

SURVEYS AND EXAMINATIONS, FIRST DISTRICT.

1889.			1890.		
June 1	To balance	$2,744.91	June 30	By amount expended to date	$903.46
			June 30	By balance	1,841.45
		2,744.91			2,744.91

HICKMAN, KENTUCKY.

1889.			1890.		
June 1	To balance, including estimated liabilities	$78,007.78	June 30	By amount expended to date	$26,071.19
			June 30	By amount expended by general service	3,288.83
			June 30	By balance	48,647.78
		78,007.78			78,007.78

COLUMBUS, KENTUCKY.

1889.			1890.		
June 1	To balance, including estimated liabilities	$39,324.87	June 30	By amount expended to date	$23,709.63
			June 30	By amount expended by general service	2,599.08
			June 30	By liabilities	140.00
			June 30	By balance	12,876.16
		39,324.87			39,324.87

FIRST DISTRICT.

Disbursements made under appropriations for improving Mississippi River, acts of August 5, 1886, and August 11, 1888.

[June 1, 1889, to June 1, 1890.]

Contracts made with—	For what made.	Disbursements under contract.	Total.
J. J. Carr	Piling	$32.46	$32.46
Madison Marine Railway Company (balance)*	Hull and cabin of tow-boat.	6,000.00	6,000.00
Hunter & Trey	Willow brush and poles.	20,664.63	20,664.63
Bryant & Picket	....do	7,064.43	7,064.43
Total		33,761.52	33,761.52

*Original contract for $10,000; part payment reported in 1889.

Disbursements made otherwise than under contract.

For what expended.	By public notice and sealed proposals.	In open market.	Liabilities.	Total.
Material and supplies	$30,871.06	$26,617.75	$875.70	$58,364.51
Subsistence	24,328.52	10,890.52	1,429.16	36,648.20
Services		132,316.95	3,620.00	135,936.95
Tools and appliances	2,961.02	10,739.41	7.50	13,707.93
Miscellaneous	641.35	3,026.50	477.60	4,145.45
Total	58,801.95	183,591.13	6,409.96	248,803.04

Abstract of proposals for furnishing willow brush and poles for Plum Point Reach, received in response to advertisement dated June 12, 1889, and opened July 12, 1889, by Capt. Smith S. Leach, Corps of Engineers, U. S. Army.

No.	Name and address of bidder.	10,000 cords of willow brush.	2,000 cords of willow poles.	Total.	Remarks.
		Per cord.	*Per cord.*		
1	Hunter & Frey, Memphis, Tenn..	$1.07	$1.65	$14,000	Accepted.
2	Franklin & Vance, Garvey, Ark..	1.15	2.00	7,750	Bids made for one-half of required quantities.

Abstract of proposals for furnishing willow brush and poles for Hickman and Columbus, Kentucky, received in response to advertisement dated June 20, 1889, and opened July 20, 1889, by Captain Smith S. Leach, Corps of Engineers, U. S. Army.

No.	Name and address of bidder.	10,000 cords of willow brush.	2,000 cords of willow poles.	Total.	Remarks.
		Per cord.	*Per cord.*		
1	A. C. Terrell, Memphis, Tenn.....	$1.20	$1.62½	$15,250	
2	Whitney Gilbreath, Ava, Ill.....	1.20	1.50	15,000	
3	Agnus McDonald, Memphis, Tenn.	1.20	1.75	15,500	
4	Nathan W. Tucker, St. Louis, Mo.	.....	.....	.....	No prices stated in proposals.
5	Bryant & Picket, Highman, Ky..	1.05	1.25	6,500	Bids made for one-half of required quantities *accepted.*
6	Vance & Franklin, Garvey, Ark.	1.15	1.70	14,150	

IMPROVING MISSISSIPPI RIVER.

Itemized statement of expenditures on works of construction in first district, from June 1, 1889, to June 1, 1890.

Articles.	Care and repairs of plant.	Surveys.	Fletcher's Bend Revetment.	Elmot Chute Dike.	Island 30 Chute Dike.
Coal	$1,221.18	$628.57	$367.96	$767.19	$334.93
Iron	961.37	63	1.50	7.25	3.31
Lumber	2,587.59	.....	.....	9.16	96
Nails	92.52	.....	.....	.....	.....
Oakum	635.17	.....	.....	.....	.....
Oil and supplies	305.20	42.00	16.33	83.57	50.45
Paint	386.98	.....	.....	.....	.....
Pipe fittings	328.38	.....	.....	.....	.....
Rope	.....	.....	78.60	.....	21.60
Spikes	212.71	.....	66.00	230.55	104.33
Towing	7,044.80	.....	1,237.05	1,290.82	774.41
Piling	46.40	.....	.....	3,761.14	2,028.88
Wire and wire stands	.....	.....	1,555.77	2,123.73	1,540.79
Brush	.....	.....	5,440.06	127.25	.....
Poles	.....	.....	872.41	148.00	.....
Stone	.....	.....	7,942.70	64.80	.....
Miscellaneous	1,080.83	32.31	1.25	24.51	11.62
Superintendence and labor	45,080.02	4,714.94	11,249.68	11,002.11	5,443.69
Total	59,983.15	5,418.45	28,729.31	19,640.08	10,314.97

Itemized statement of expenditures on works of construction, etc.—Continued.

Articles.	Daniel's Point Revetment.	Plum Point Revetment.	Hickman, Ky.	Columbus, Ky.	Total.
Coal	$2,088.36	$385.17	$576.15	$633.15	$6,902.66
Iron	42.34	1.20	59.56	30.17	1,107.27
Lumber	4.95	.....	139.49	.....	2,742.15
Nails	1,40	.....	11.80	.....	105.72
Oakum	3.67	.....	.....	.....	638.84
Oil and supplies	93.04	7.65	123.00	75.88	796.62
Paint	.....	.....	6.66	.....	393.64
Pipe fittings	.....	.....	.....	.....	328.38
Rope	57.44	45.00	66.25	117.71	386.60
Spikes	147.20	16.50	35.75	72.30	885.34
Towing	4,427.27	521.53	679.73	1,267.47	17,243.08
Piling	.....	.....	36.40	121.44	5,994.26
Wire and wire strands	4,818.07	572.83	959.91	910.53	12,481.63
Brush	20,343.34	1,930.59	3,285.45	2,777.25	33,903.94
Poles	2,401.29	245.73	476.00	525.62	4,669.05
Stone	14,602.83	2,189.49	4,482.75	3,716.28	32,998.85
Miscellaneous	216.27	1.20	93.37	301.19	1,762.55
Superintendence and labor	47,448.92	4,802.77	11,136.09	12,156.84	153,035.00
Total	96,696.39	10,719.66	22,168.80	22,705.33	276,875.64

Statement of expense for work done at Hickman, Kentucky, from August 28, 1889, to May 31, 1890.

Items.	Administration.	Care of plant.	General repairs.		Tow-boat service.		Subaqueous mattress.					
							Chinese anchor.		Mattress.		Total.	
	Cost.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.
Labor	$1,778.98	$590.44	.....	$658.87	.....	$1,268.32	.....	$375.92	.....	$3,272.07	.....	$3,637.99
Subsistence	80.81	205.39	.....	27.53	.....	162.22	.....	60.72	.....	44.06	.....	104.78
Brush, cords									1,812	1,902.60	1,812	1,902.60
Poles, do									250	312.50	250	312.50
Stone, cubic yards							20	29.22	1,697	2,478.92	1,717	2,508.14
Wire, pounds							462	13.75	22,098	608.08	22,560	621.83
Wire strands, do									4,061	145.79	4,061	145.79
Spikes and nails, do			300	11.80					1,000	27.50	1,000	27.50
Lumber, feet			4,088	49.39			2,785	27.85	4,200	47.25	6,985	75.10
Coal, bushels					2,729	272.90						
Iron, pounds							1,240	15.80	240	4.80	1,480	20.60
Miscellaneous	127.97			72.57		6.66						
Manilla rope, pounds									700	72.55	700	72.55
Oils and supplies		14.61				29.02						
Piling, feet									455	36.40	455	36.40
Total	1,987.76	910.44	.....	820.16	.....	1,739.12	.....	523.26	.....	8,942.52	.....	9,465.78
Percentage	8.27	3.78	.....	3.41	.....	7.23	.....	2.16	.....	37.25	.....	39.41
Work done											2,736 squares made. 2,624 squares covered.	
Cost per unit											$4.47 per square made. $4.66 per square covered.	

Statement of expense for work done at Hickman, Kentucky, from August 28, 1889, to May 31, 1890—Continued.

Items.	Shore-work.						Grand total.		Percentage.
	Grading.		Mattress.		Total.				
	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	
Labor		$2,358.91		$2,212.50		$4,571.41		$12,606.01	52.51
Subsistence		261.00		44.00		305.00	1,694	885.73	3.68
Brush, cords			1,317	1,382.85	1,317	1,382.85	3,129	3,265.45	13.67
Poles, do			131	163.50	131	163.50	381	476.00	1.97
Stone, cubic yards			1,508	2,202.90	1,508	2,202.90	3,225	4,711.04	19.61
Wire, pounds			5,524	155.10	5,524	155.10	28,084	776.93	3.22
Wire strands, do							4,061	145.79	.60
Spikes and nails, do			300	8.25	300	8.25	1,600	47.55	.20
Lumber, feet	1,000	15.00			1,000	15.00	71,775	139.49	.58
Coal, bushels	2,292	229.20			2,292	229.20	5,021	502.10	2.07
Iron, pounds							1,480	20.60	.08
Miscellaneous								207.20	.86
Manilla rope, pounds							700	72.55	.30
Oils and supplies		76.58				76.58		120.21	.50
Piling, feet							455	36.40	.15
Total		2,940.69		6,169.10		9,109.79		24,003.05	100.00
Percentage		12.21		25.69		37.90			100.00
Work done	970 linear feet.				1,378 squares made. 143 feet wide.		4,114 squares made. 4,002 squares covered. 970 linear feet.		
Cost per unit	$3.03 per linear foot.				$3.54 per square. $12.18 per linear foot.		$5.71 per square made. $6 per square covered. $24.74 per linear foot.		

Statement of expense for work done at Columbus, Kentucky, from October 14, 1889, to May 31, 1890.

Items.	Administration.	Care of plant.		General repairs.	Towboat service.		Mattress work.							
							Subaqueous.		Grading.		Shore-work.		Total.	
	Cost.	Amt.	Cost.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.
Labor	$1,686.89		$1,291.87	$1,431.52		$1,601.26		$3,032.99		$1,458.96		$1,010.99		$5,502.94
Subsistence	144.20		59.06	340.43		414.97		52.60		202.74		50.00		305.34
Brush ....cords							1,310	1,375.50	80	84.00	705	740.25	2,095	2,199.75
Poles....do							148	185.62			85	106.25	233	291.87
Stone ....cubic yards							1,411	2,089.69			450	666.45	1,861	2,756.14
Wire ....pounds							11,418	319.79			5,708	159.82	17,126	479.61
Wire strand....do							2,034	73.03					2,034	73.03
Spikes ....do		40	1.20				1,300	36.40			200	5.50	1,500	41.90
Lumber....feet		500	7.50											
Coal ....bushels					4,586	458.65	200	20.00	1,545	154.50			1,745	174.50
Iron....pounds		325	7.83				260	5.20					260	5.20
Rope....do							820	102.65					820	102.65
Oils and supplies			4.15	27.10		26.26				9.62				9.62
Piling ....feet							759	60.72					759	60.72
Miscellaneous	141.42		213.17	46.25		37.27								
Total	1,972.73		1,584.78	1,845.30		2,538.41		7,354.19		1,909.82		2,739.26		12,003.27
Percentage	8.47		6.80	7.92		10.90		31.57		8.20		11.76		51.53

Statement of expense for work done at Columbus, Kentucky, from October 14, 1889, to May 31, 1890—Continued.

Items.	Crib dikes.						Grand total.		Percentage.
	Shore cribs.		Subaqueous cribs.		Total.				
	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	
Labor	.....	$319.00	.....	$739.20	.....	$1,058.20	.....	$12,572.68	53.97
Subsistence	.....	7.82	.....	40.00	.....	47.82	.....	1,317.04	5.65
Brush ..... cords	183	192.50	367	385.00	550	577.50	2,645	2,777.25	11.92
Poles ..... do	60	75.00	127	158.75	187	233.75	420	525.62	2.26
Stone ..... cubic yards	200	296.10	450	666.45	650	962.55	2,511	3,718.69	15.95
Wire ..... pounds	4,000	112.11	8,000	224.24	12,000	336.35	29,126	815.96	3.50
Wire strand ..... do	.....	.....	600	21.54	600	21.54	2,634	94.57	0.41
Spikes ..... do	350	10.25	750	20.15	1,100	30.40	2,640	78.50	0.33
Lumber ..... feet	.....	.....	.....	.....	.....	.....	500	7.50	0.03
Coal ..... bushels	.....	.....	.....	.....	.....	.....	6,331	633.15	2.72
Iron ..... pounds	40	.80	100	2.00	140	2.80	725	15.83	0.07
Rope ..... do	.....	.....	120	15.06	120	15.06	940	117.71	0.51
Oils and supplies	.....	.....	.....	.....	.....	.....	.....	67.13	0.29
Piling ..... feet	.....	.....	759	60.72	759	60.72	1,518	121.44	0.52
Miscellaneous	.....	.....	.....	.....	.....	.....	.....	438.11	1.88
Total	.....	1,013.58	.....	2,333.11	.....	3,346.69	.....	23,291.18	100.00
Percentage	.....	4.35	.....	10.01	.....	14.36	.....	.....	100.00
Work done	.....	.....	.....	.....	.....	.....	130,000 feet crib. 800 linear feet mattress. 2,717 square mattress.		
Cost per unit	.....	.....	.....	.....	.....	.....	$0.04 per cubic foot. $22.65 per linear foot. $6.70 per square.		

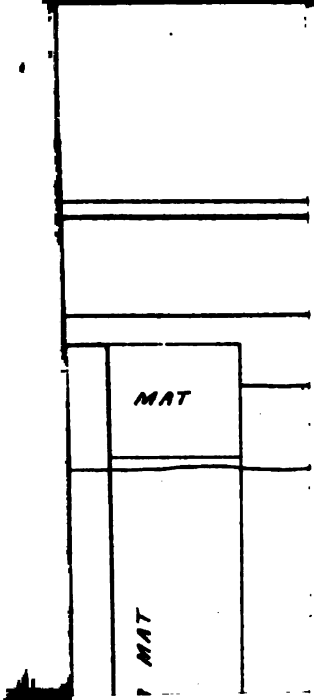
Approximate value of plant belonging to the United States and used upon the improvement of the Mississippi River, first district.

Class of property.	No.	Approximate value May 31, 1890.	Class of property.	No.	Approximate value May 31, 1890.
Steamer *Titan*	1	$25,000	Derrick-boats	1	$2,5
Steamer *P. Kirns*	1	5,787	Barges	23	12,7
Steamer *Itasca*	1	5,996	Machine-shop boats	1	2,4
Steamer *Abbott*	1	3,025	Floating dock	1	7,6
Launch *Titania*	1	454	Skiffs	24	2
Pile-drivers	28	43,814	Tools and appliances and machinery	....	13,2
Quarter-boats	14	19,754	Office furniture	....	1
Mattress-boats	6	8,874	Surveying instruments	....	1
Mooring-barges	2	4,388			
Sand-pump	1	2,793			
Graders	2	17,349	Total		176,2

Table showing comparative least channel depths and velocities in various channels of the improved portion of Plum Point Reach, Mississippi River.

Localities.		First group.				Second group.			
		Lower Plum Point Crossing.		Bullerton Channel.		Island 80 Channel.		Lynch Channe	
Date.	Gauge.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velo
1889.									
June 5	15.75	31.1	4.03	11.5	3.20	31.0	5.84	18.0	
11	16.20	31.0	4.11	11.5	3.23	33.0	5.80	16.0	
14	17.75	33.0	4.00	14.0	.....	35.0	5.46	18.0	.....
17	17.70	34.0	4.03	16.0	3.26	33.5	5.81	18.0	
24	21.50	37.0	4.18	18.0	3.78	38.5	5.65	25.0	
July 5	14.50	31.0	3.92	8.0	3.15	29.0	4.73	15.0	
9	11.60	28.0	4.04	3.5	2.76	27.0	4.52	10.0	
15	11.25	26.5	3.89	.....	.....	26.5	4.85	8.0	
19	12.25	27.5	4.00	5.5	3.04	27.0	5.00	9.5	
29	12.50	27.5	3.96	5.5	.....	28.0	4.92	9.0	.....
Aug. 2	11.20	28.0	4.14	4.0	2.86	26.0	4.45	9.0	
9	10.70	26.0	4.27	2.5	1.82	27.0	5.53	8.0	
16	7.90	22.0	4.45	.....	.....	24.0	5.30	5.0	
21	6.70	20.0	5.30	.....	.....	23.0	5.42	3.0	
29	4.30	19.0	5.88	.....	.....	24.0	5.50	1.0	
Oct. 3	2.00	13.0	3.98	.....	.....	16.5	4.76	1.5	
9	1.80	12.0	4.48	.....	.....	15.0	5.11	3.0	
14	0.00	12.0	4.53	.....	.....	13.0	4.95	2.0	
22	—2.00	10.0	4.14	.....	.....	13.0	3.75	2.0	
29	—1.70	10.0	3.95	.....	.....	13.0	3.83	2.5	
Nov. 7	1.00	13.0	3.21	.....	.....	19.0	4.60	6.0	
15	8.90	22.0	3.29	0.7	.....	28.0	4.72	12.5	
22	16.60	32.0	3.37	8.5	3.56	36.0	3.56	20.0	
29	16.55	31.0	4.57	9.0	2.59	35.0	3.33	21.0	
Dec. 5	18.10	32.0	4.37	11.0	3.67	35.0	4.60	20.0	
12	10.80	24.5	5.53	2.5	1.31	29.0	5.03	11.0	
19	10.25	23.0	4.14	2.0	1.48	30.0	5.03	11.0	
27	10.60	24.0	4.49	2.5	2.09	28.0	4.49	11.0	
1890.									
Jan. 2	10.00	23.0	4.41	2.5	1.63	28.0	4.72	10.5	
17	26.00	38.0	4.56	18.0	.....	44.0	5.11	25.0	
24	29.30	43.0	4.26	20.0	3.52	45.0	5.38	29.0	
31	29.30	44.0	4.53	23.0	3.05	48.0	4.91	28.0	.....
Feb. 7	24.30	39.0	4.22	18.0	.....	39.0	4.22	26.0	.....
13	26.00	40.0	4.26	20.0	4.06	40.0	4.87	27.0	
21	28.00	42.0	3.95	22.0	4.14	45.0	4.10	32.0	
Apr. 28	23.25	38.0	4.49	11.0	4.64	36.0	5.49	28.0	
May 6	23.78	37.0	4.91	16.0	4.33	36.0	6.19	25.0	
13	18.45	30.0	4.17	12.0	3.75	32.0	5.18	20.0	

NOTES.—The depths reported are the least found in the line of deepest water, or those which limit navigation for the time being. The velocities were measured on the same line and near the shoal point. They were all taken with the current-meter running at a depth of 5 feet below the surface. They are individual velocities taken to ascertain the relative draught of water in the different channels, and are useful for that purpose only. They have no relation to the average velocity or discharge.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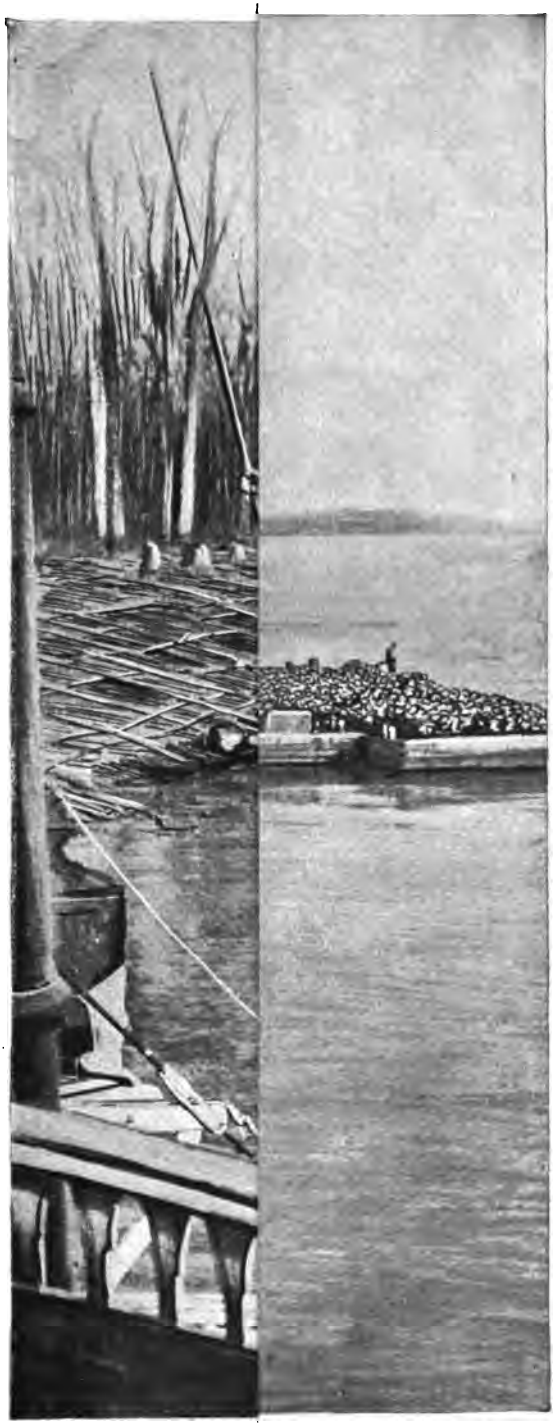
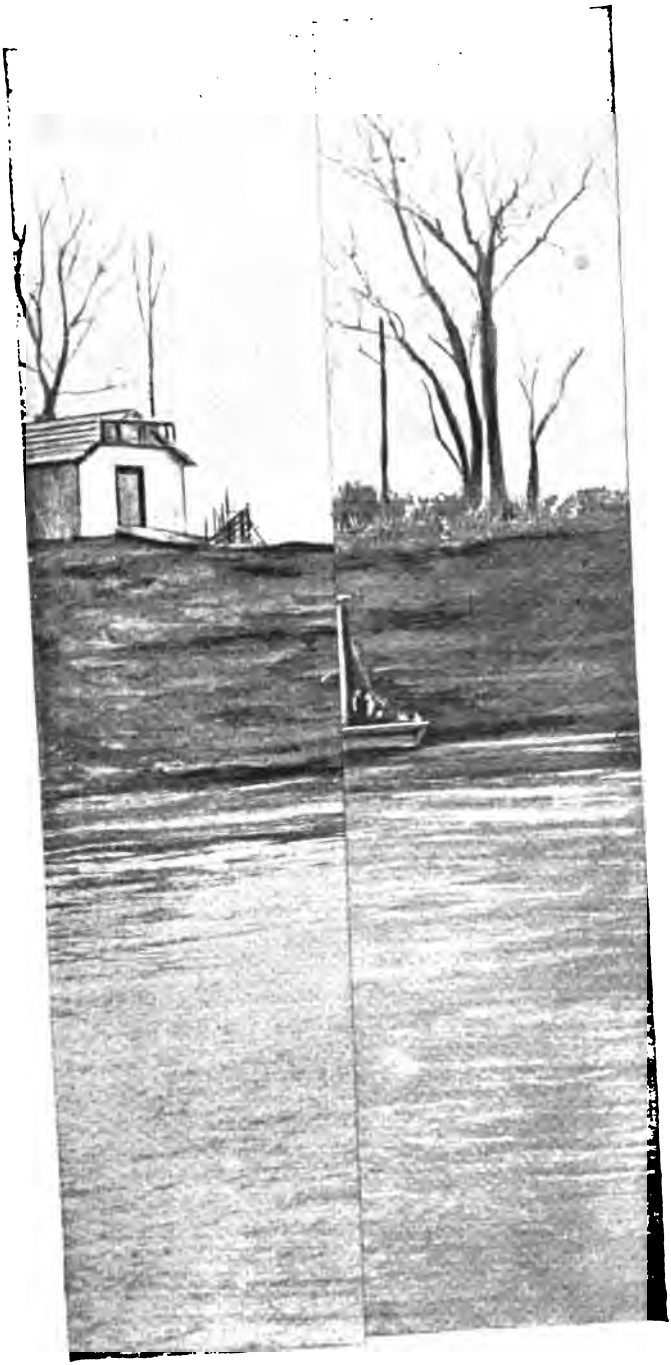
Statement of expense for work done at Columbus, Kentucky, from October 14, 1889, to May 31, 1890.

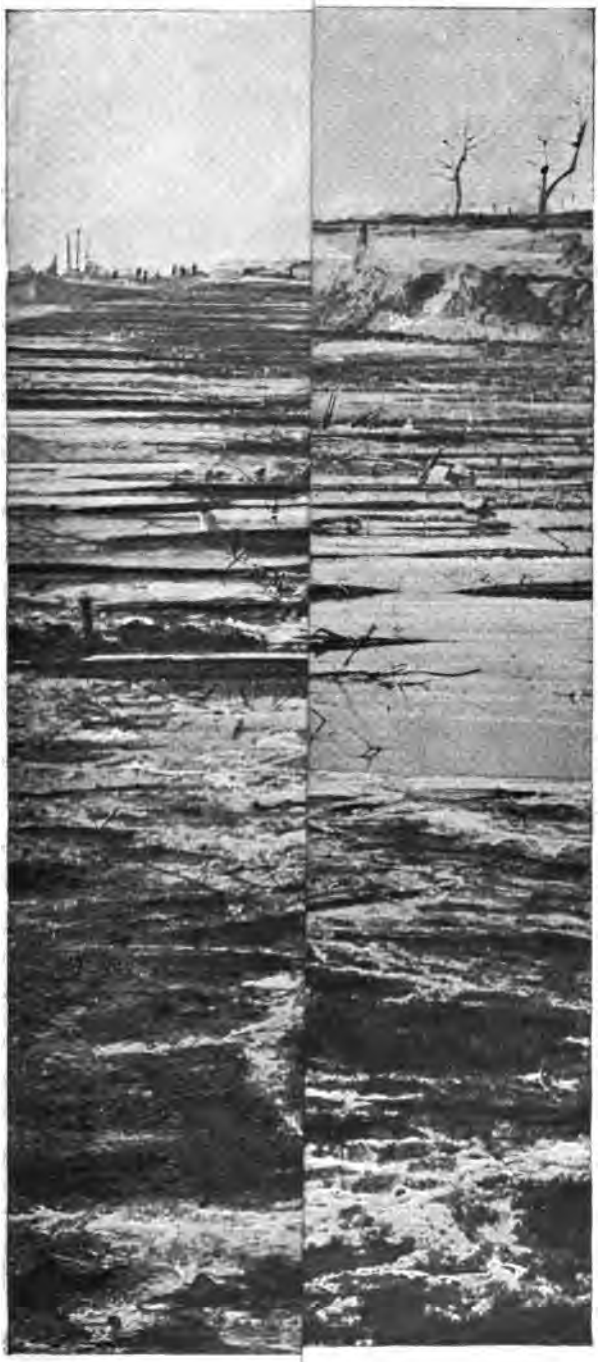
Items.	Administration.	Care of plant.		General repairs.	To w-boat service.		Mattress work.							
							Subaqueous.		Grading.		Shore-work.		Total.	
	Cost.	Amt.	Cost.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.
Labor	$1,686.89		$1,291.87	$1,431.52		$1,601.26		$3,032.99		$1,458.96		$1,010.99		$5,502.94
Subsistence	144.20		59.06	340.43		414.97		52.60		202.74		50.00		305.34
Brush ....cords							1,310	1,375.50	80	84.00	705	740.25	2,095	2,199.75
Poles....do							148	185.62			85	106.25	233	291.87
Stone ....cubic yards							1,411	2,089.69			450	666.45	1,861	2,756.14
Wire ....pounds							11,418	319.79			5,708	159.82	17,126	479.61
Wire strand....do							2,034	73.03					2,034	73.03
Spikes ....do		40	1.20				1,300	36.40			200	5.50	1,500	41.90
Lumber....feet		500	7.50											
Coal ....bushels					4,586	458.65	200	20.00	1,545	154.50			1,745	174.50
Iron ....pounds		325	7.83				260	5.20					260	5.20
Rope ....do							820	102.65					820	102.65
Oils and supplies			4.15	27.10		26.26				9.62				9.62
Piling ....feet							759	60.72					759	60.72
Miscellaneous	141.42		213.17	46.25		37.27								
Total	1,972.73		1,584.78	1,845.30		2,538.41		7,354.19		1,909.82		2,739.26		12,003.27
Percentage	8.47		6.80	7.92		10.90		31.57		8.20		11.76		51.53

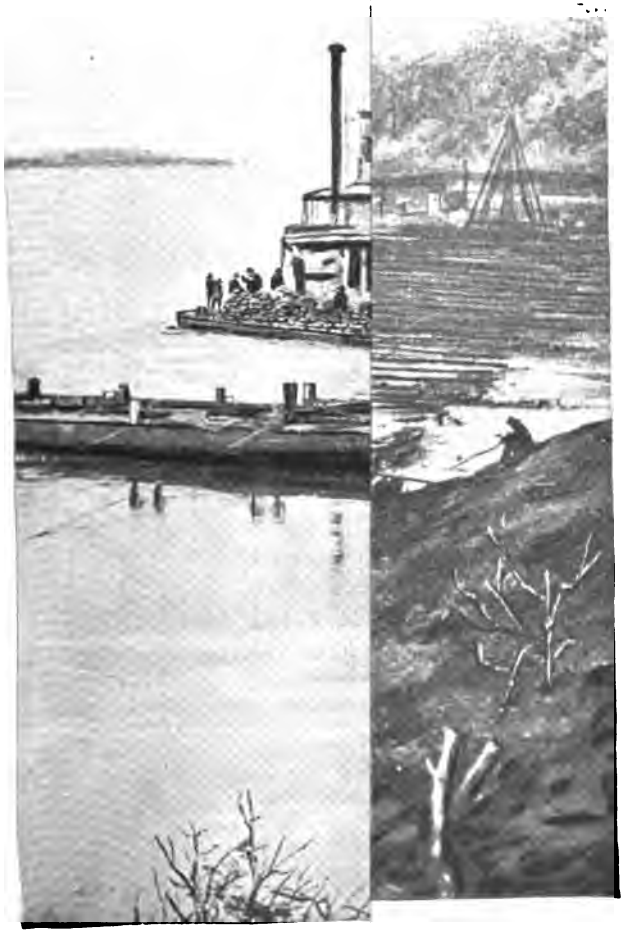
Statement of expenses for work done at Columbus, Kentucky, from October 14, 1889, to May 31, 1890—Continued.

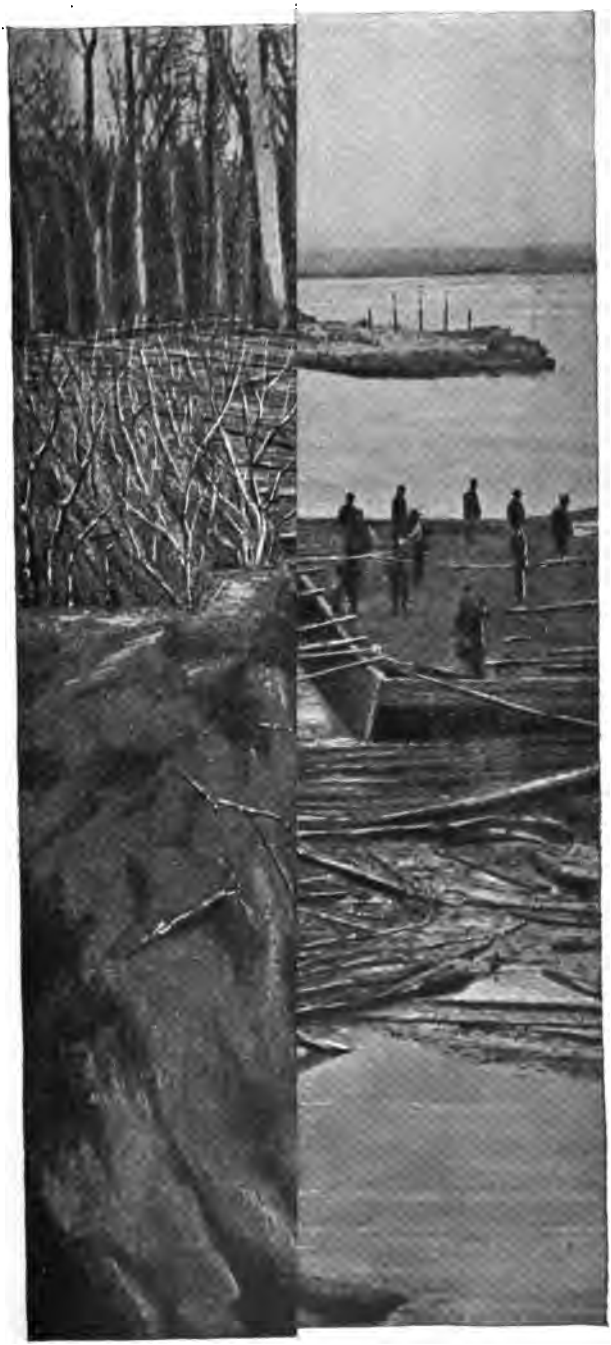
Items.	Crib dikes.						Grand total.		Percentage.
	Shore cribs.		Subaqueous cribs.		Total.				
	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	
Labor	.....	$319.00	.....	$739.20	.....	$1,058.20	.....	$12,572.68	53.97
Subsistence	.....	7.82	.....	40.00	.....	47.82	.....	1,317.04	5.65
Brush ..... cords	183	192.50	367	385.00	550	577.50	2,645	2,777.25	11.92
Poles ..... do	60	75.00	127	158.75	187	233.75	420	525.62	2.26
Stone ..... cubic yards	200	296.10	450	666.45	650	962.55	2,511	3,718.69	15.95
Wire ..... pounds	4,000	112.11	8,000	224.24	12,000	336.35	29,126	815.96	3.50
Wire strand ..... do	.....	.....	600	21.54	600	21.54	2,634	94.57	0.41
Spikes ..... do	350	10.25	750	20.15	1,100	30.40	2,640	78.50	0.33
Lumber ..... feet	.....	.....	.....	.....	.....	.....	500	7.50	0.03
Coal ..... bushels	.....	.....	.....	.....	.....	.....	6,331	633.15	2.72
Iron ..... pounds	40	.80	100	2.00	140	2.80	725	15.83	0.07
Rope ..... do	.....	.....	120	15.06	120	15.06	940	117.71	0.51
Oils and supplies	.....	.....	.....	.....	.....	.....	.....	67.13	0.29
Piling ..... feet	.....	.....	759	60.72	759	60.72	1,518	121.44	0.52
Miscellaneous	.....	.....	.....	.....	.....	.....	.....	438.11	1.88
Total	.....	1,013.58	.....	2,333.11	.....	3,346.69	.....	23,291.18	100.00
Percentage	.....	4.35	.....	10.01	.....	14.36	.....	.....	100.00
Work done	.....	.....	.....	.....	.....	.....	130,000 feet crib. 800 linear feet mattress. 2,717 square mattress.		
Cost per unit	.....	.....	.....	.....	.....	.....	$0.04 per cubic foot. $22.65 per linear foot. $6.70 per square.		



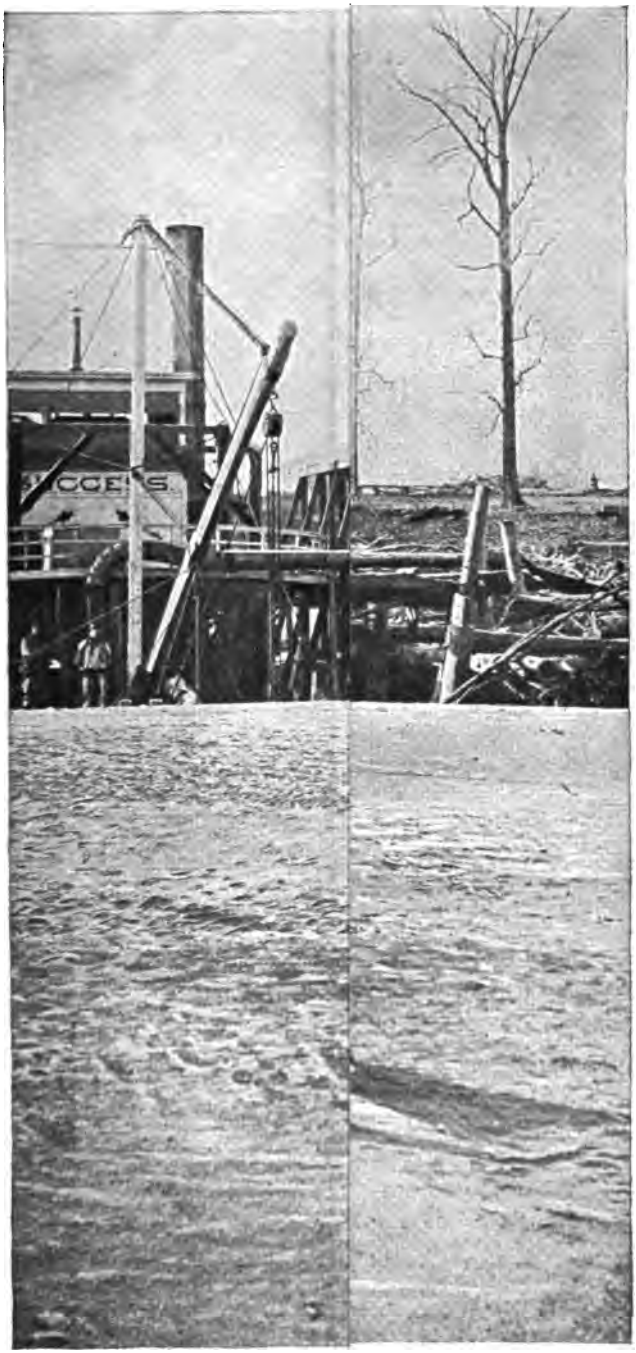


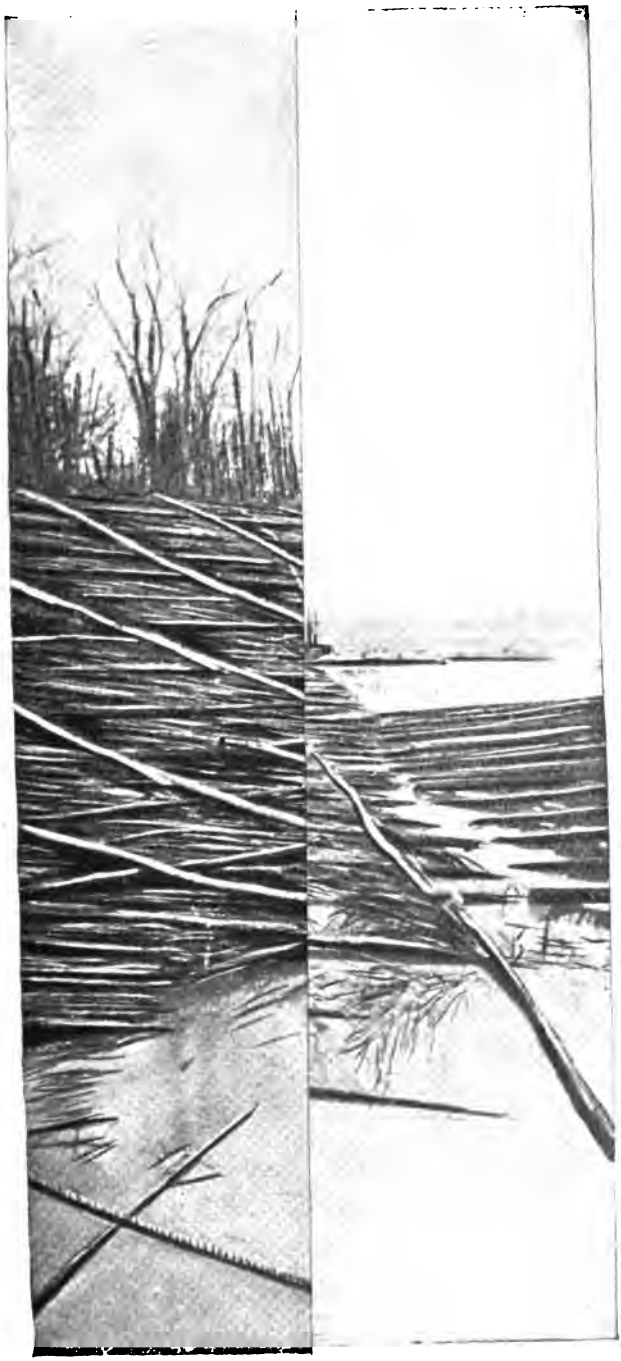






No. 17. VIEW OF EXPERIMENT[illegible]ORK WAS DONE THE WATER





NEING.

The crossings forming group 1 of the table may be considered as competitors for the channel over Bullerton Bar. Bullerton Channel has remained partly obstructed by the diverting action of the works favoring the first channel, which latter has remained good by reason of carrying the water diverted from the other. The two channels of the second group are also competitors, of which the second has been restricted by the direct action of the Fletcher's revetment, and the first, Island 30, has carried the bulk of the water and remained good.

Commerce, trade, manufacture, and navigation of the city of Cairo, Illinois, for the year ending April 30, 1890.

Articles.	Quantity.	Value.	Articles.	Quantity.	Value.
Shipped North by river:	*Tons.*		Shipped South by river:	*Tons.*	
Cotton	14,989	$2,699,110.00	Oats	23,944	$573,600.96
Lumber	31,950	240,909.12	Hay	7,134	92,742.00
Corn	6,404	92,225.88	Bran	4,510	72,160.00
Oats	1,955	29,108.16	Provisions	760	106,505.00
Hay	1,496	17,952.00	Flour	4,172	177,318.50
Merchandise	7,000	1,080,980.00	Corn-meal	5,683	113,676.00
Flour	13,355	567,596.00	Merchandise	2,029	852,138.00
Tobacco	1,350	202,500.00	Lumber	22,050	178,240.00
Fruits and vegetables	5,509	72,229.80	Coal	135,809	271,618.00
Shipped South by river:			Salt	7,590	113,850.00
Wheat	25,473	1,018,950.00			
Corn	20,144	282,019.15	Total	343,306	3,970,737.49

APPENDIX G.

REPORT OF CAPT. S. S. LEACH, CORPS OF ENGINEERS, UPON OPERATIONS IN THE SECOND DISTRICT.

UNITED STATES ENGINEER OFFICE,
Memphis, Tenn., June 1, 1890.

GENERAL: I have the honor to submit the following report of operations in the second district under the appropriation for improving Mississippi River, act of August 11, 1888, from May 31, 1889, to May 31, 1890.

The part of the river to which this report relates, known as the second district, extends from the foot of Island 40 to the mouth of White River, a distance of 130 miles.

MEMPHIS HARBOR.

In the last annual report mention was made of a recommendation to the Secretary of War to apply a portion of the balance under this title to converting into permanent structures the parts above low water of the Citizen's dikes, at the lower end of the protected front. This was not included in the original design, as it was hoped that accretions during the life of the brush-cribs would nearly or quite cover and supersede them. This expectation has not been realized, and it having become necessary to strengthen or lose them, the plan of conversion was adopted. The project was duly approved and its execution begun in October, 1889. The main dikes, 2, 3, 4, and 5, were completed before the rising river put a stop to the work. Dike No. 1 required but little and that not of the first importance. It is now entirely masked by earth dumped above it by various parties. Each of the four dikes named was covered with earth, topped with a layer of gravel 1 foot thick and a paving of stone 10 inches thick, the hole so disposed as to have its net crest-line coincident with the crest of the crib-dike when new, with a grass grade higher at all points by one-fifth of the height of fresh earth, and cross profiles of 20-foot crown, 4 to 1 slope down and 2½ to 1 slope up-stream. At the lower end the embankment rested against a toe or abutment of random stone, which was carefully developed without breaking into the paving.

The materials were procured by open-market purchase, the earth at 34½ cents per cubic yard placed in the embankment to lines and grades, the gravel at 30 cents per yard loaded on barges delivered at the work, and the stone at $2 per yard under the same conditions. The gravel and stone were placed by hired labor. Some stone in addition to first estimates was required by reason of the sliding and sinking of the riprap abutments. It was obtained from the reserve stock of the Hopefield revetment, and was handled by hired labor. Besides the trouble with the abutments, work was retarded and made more costly by the stage of the river which, after a few days at low stage, began rising rapidly, making it necessary to transfer men and material from one dike to another with great frequency to keep ahead of the water.

A tabulated exhibit herewith shows the cost of this work in detail.

which cut the season in two, and when work had to be suspended, while expenses could not be, but an indifferent showing could be made, and at the end the exhaustion of funds found the project not completed.

A third floor-mat at the site of Dike No. 1 was completed and successfully sunk on September 24. The single crib forming this dike was at once begun and was sunk on the 30th, completing the subaqueous portion of Dike No. 1. The crib is 20 feet wide, 250 feet long, and varies in height from 6 to 12 feet, to bring its top on the required crest line. During the first half of October the subaqueous part of Dike No. 2 was completed, consisting of floor-mat 200 by 330 feet, and two cribs, one 260 by 30 by 8 feet, and one 275 by 18 by 6 feet. In the last half of the same month the floor-mats of Dikes 3, 4, and 5 were laid, as the stage of river was favorable for that part of the work.

On October 15 a slide in the bank occurred, exactly on the line of No. 4 dike. A few days later it extended down stream to the axis of No. 5. It made necessary a modification of the plan of No. 4 by extending the floor mat and cribs inshore to the edge of the slip, to protect the disintegrated earth and fill out the profile of the dike. This change increased the cost of the dike and helped to create the deficit.

By the middle of November Crib 1 of Dike 3 was in place and Crib 2 of same dike and Crib 1 of Dike 4 were partly built. The river had reached a 16-foot stage and was rising fast, making further operations on the river impossible and limiting them to the shore end of No. 4 and embankments of 1, 2, and 3. These parts of the work were finished by the end of November and operations entirely suspended to await the decline of the river. The high stage continued during December, and when early in January the falling river reached a stage at which operations could be resumed, it almost immediately began to rise. The partly finished second crib of Dike 3 was completed and sunk on January 13, and operations were then discontinued.

The portion of the dikes completed and that remaining to be done are shown on the map of the locality herewith.

The magnitude of the difficulties encountered during this season and relied upon to excuse the failure to complete the project within the estimated cost may be better appreciated by the consideration of some administrative details. The expenditures for administration and care of plant were greater by $3,000 than they should have been on the basis of the percentages realized in the case of the Memphis dikes, the only similar work available for comparison. This represents a part of the direct loss from the interruption of work by high water. A similar comparison gives an excess of $1,000, under the head of general repairs, a sum which represents the unusual breakage and other damage due to the excessive strain to which the whole plant was subjected. At the beginning of the season cordage was supplied sufficient in quantity for all requirements, as estimated from previous experience. Before the close it had been necessary to supply over $2,000 worth in addition to meet the losses by breakage and to provide the extra strength which was plainly required. Each dollar of this represents another one, and perhaps more, involved in delays and the handling and rehandling of the extra lines. All this is in addition to the value of the two mats lost, say $5,000, a sum which alone exhausts the percentage usually estimated for contingencies. Even with this loss, under the most unfavorable conditions encountered elsewhere in the experience of the present writer, the project could have been completed with the funds available.

The financial statement and other exhibits herewith show in detail the cost of the work done and the balance of the appropriation remaining on hand. The latter consists exclusively of materials for construction, purchases in the principal lines having been made at the beginning of the season and for the full amounts of the estimates. Based on the known quantity of work to be done and the known cost of that already done, with allowance for the increased expense due to a mobilization of plant for such a small expenditure, it is estimated that an additional sum of $15,000 will be necessary to the completion of the project, and it is recommended that the sum named be provided by allotment if it should not have been done by appropriation.

DETAILS OF CONSTRUCTION.

Under the present appropriation there have been constructed in the first and second districts, since September, 1888, over 4¼ miles of subaqueous mattress of all kinds, of which 3¼ miles have formed part of completed standard revetment. This has been in fact the first period of genuine activity since the beginning of 1885. Its experiences have contributed greatly to the development of a satisfactory type of continuous revetment, the fundamental requirements of which are now clearly seen and its principal lines of future improvement strongly indicated.

The matter of first importance is a sufficient width of subaqueous mattress, for if that be undetermined the revetment may be carried out bodily, or so broken up, both below and above the water, as to lose its resisting power. It is manifestly desirable that the outer edge of the mat should reach to or beyond the *thalweg*, and in most

cases of banks needing protection it can be so arranged. It happens that the width from low-water line required to do this seldom falls enough below 200 feet to offset the advantages of uniformity in that regard, and that width may now be accepted as a minimum for the upper part of the river. From this minimum the width may be increased as seems necessary. It will be better to keep the inside edge at low water and weave a mat of the desired width. Should the available mooring and weaving plant lack something of this width, the inside edge may be held out 25 or 30 feet and the connection extended to join it. This was done at Daniel's Point, when, with only 200 feet of mooring and weaving barges, the outer edge of the subaqueous mat was left 225 feet from low water. A braced bent of piles should always be driven to take the thrust of the mooring-barges, and a line of single piles 50 feet apart along the inside edge of the mat is a great convenience in weaving and sinking. All these piles should be pulled before the work closes, or, if that is too difficult, they should be cut off at the level of the mat. If left they are most dangerous obstructions.

It is in the construction and sinking of the subaqueous mattress that occur all the critical situations, interruptions, disasters, and losses, which, though constantly decreasing with added skill and experience, have up to the present time made the cost of such work sometimes excessive and always uncertain. They have hampered the administration of the work by making it impossible to foresee when operations could be commenced or how long they might be prosecuted. They have originated almost exclusively in two causes—the presence of drift and the inefficiency of the fastenings relied upon to hold the plant in position. These fastenings have consisted of manilla head and shackle lines, the former fastened to timber-heads on the mooring-barges and the latter to straps built into the mat-head, and all led obliquely to fixed points on the bank. These large lines sagging into the water are swept by the current out of vertical planes and assume positions represented by the dotted lines on the accompanying sketch (Fig. 1). The efficiency of each line in its actual position is the same as that of a straight line having the direction of a tangent at the point of attachment to the mooring-barge. Drift lodging against the lines increases the displacement, which has the additional disadvantage of being at a maximum on the outside lines, which should be the most secure. The greatest trouble caused by drift is during the sinking. When a quantity has passed under the mooring-barges and lodged under the mat, as is usually the case, its buoyancy must be counteracted by an excess of rock placed on the mat immediately over it. The composite mass of wood and stone is in unstable equilibrium during sinking, save from the resistance of the mat to flexure. The impact of current may overcome this and cause the drift to move, when, its upward thrust and the weight of the rock no longer counterbalancing each other, the mat is torn across and partly or wholly lost. Several plans for keeping the plant clear of drift have been discussed, and on one or two occasions loaded barges have been strung along the outside line to form a sheer boom. Such devices are only partially successful, for some pieces will strike and dive under and others are water-logged and float so low that they miss the boom. It has been discovered that all the drift that can lodge in front of the mooring-barges does not cause a great strain and it has been proposed to throw out fender-barges above the mooring-barges and hang festoons of chains from them in such a way as to catch the drift and hold it until the accumulation suffices to form a natural boom. This plan was tried at Helena near the close of the season and the report upon it is sufficiently favorable to warrant its further use. The disposition of the barges and chains is shown in a sketch submitted herewith (Fig. 2). It has the additional advantage of providing a basis for an improved system of fastenings, consisting of steel cables running parallel to the current, as shown. On the map of Hickman Harbor, herewith, is shown a method of fastenings used there and with some modifications at Columbus. It meets that problem fully, but does not provide against drift. On the last mat at Daniel's Point a set of steel shackle-lines was substituted for the manilla ones, with such manifest advantage as to make it certain that the strong predilection heretofore existing in favor of manilla is baseless, and that that costly item of equipment may be greatly reduced. All head and shackle lines may be of metal with great increase of efficiency and saving of cost.

The method of connection between the sub-aqueous and shore-mats, introduced during the past year, in addition to its other advantages, contributes greatly to the ease and certainty of the difficult operation of sinking. It will be remembered that formerly the river-mat was laid with its inner edge at about the low-water line. Next the shore work was placed, extending down the slope to the actual water line at the time. The strip of bank between these lines was then covered by connecting mats. At the time of sinking, the river-mat was entirely free except at its head and except also, that cables were laid to prevent its moving out towards the river. The cables rarely had anything to do, for the tendency was usually to creep up the bank toward the foot, probably due to the greater strength of current on the outside, which took all slack out of the cables and lashings and lengthened the outer edge of the mat. By

Fig. 1

Full lines denote theoretical and dotted lines the actual lead of the head lines during construction of Subaques Mattress.

To accompany anual report dated June 1st 1890.

Sewell L Leach
Captain of Engineers

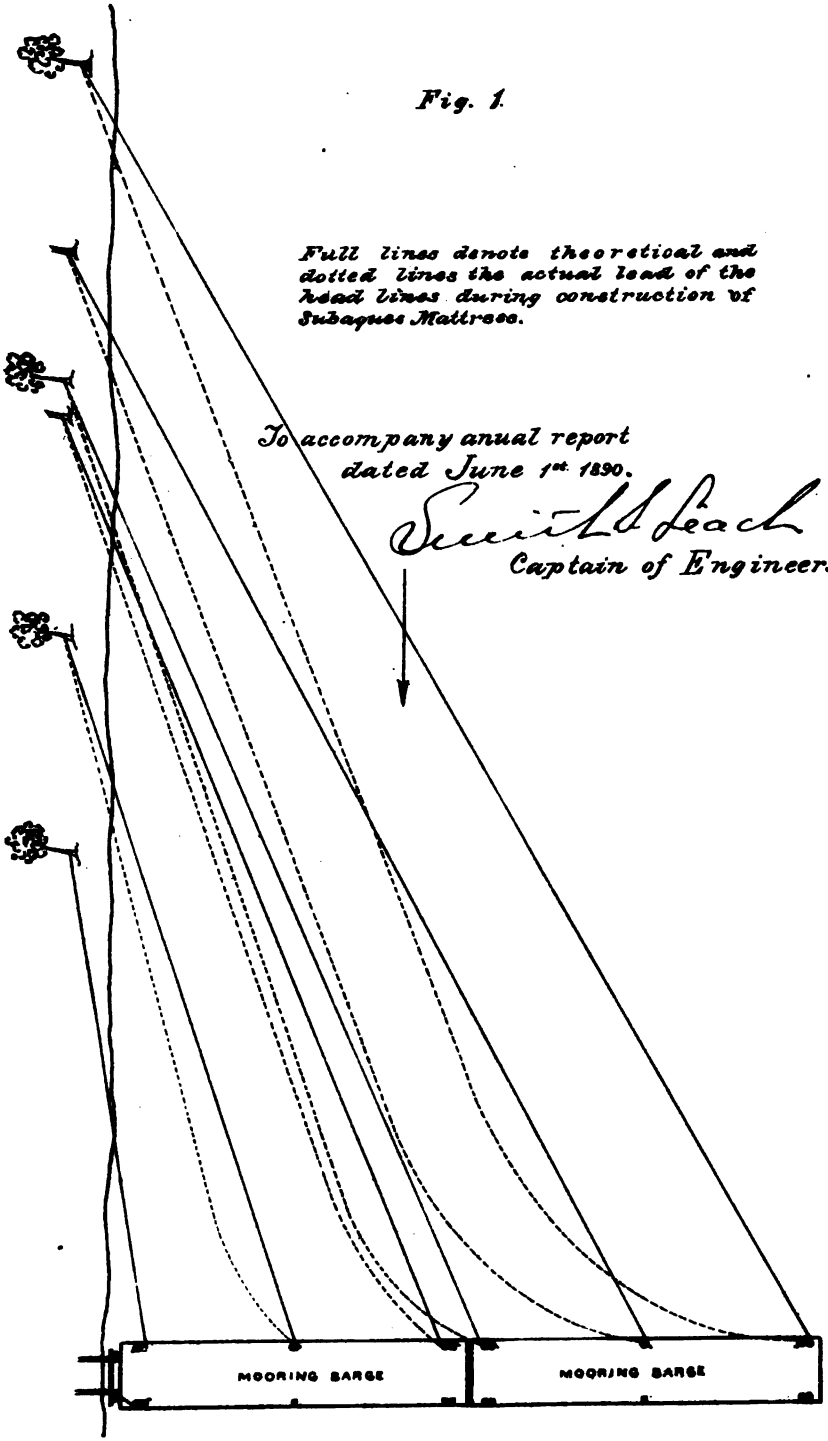
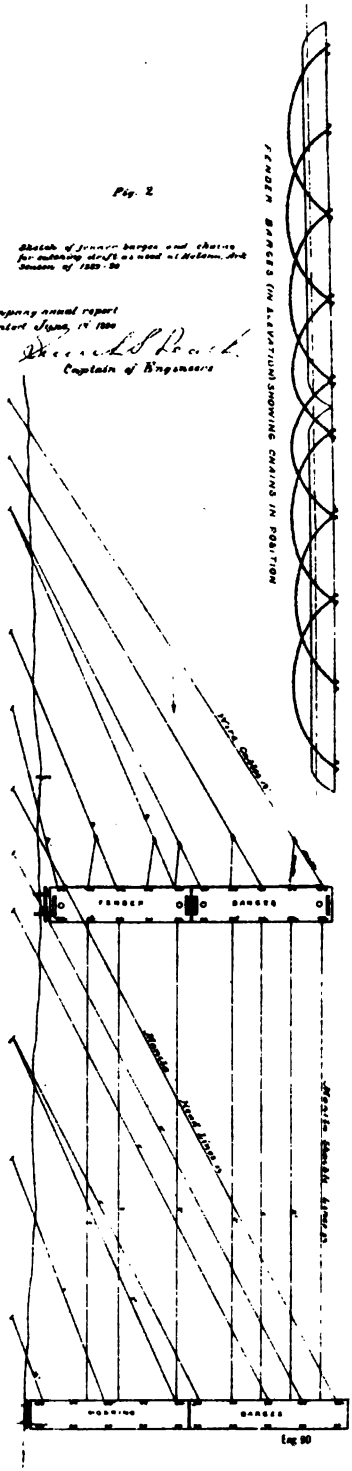


Fig. 2

Sketch of fender barges and chains for protecting draft as used at Nelson, N.S. Season of 1923-24

To accompany annual report dated June 15 1924

Captain of Engineers



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the method now in use, the connection is made before sinking, and its full strength is available during that process to hold the inner edge of the mat in position.

A second vital requirement of a good revetment is a sufficiently flat grade above low water. If the slope be too steep, slides or sloughs will occur, each displacing the corresponding portion of brush-work and tearing it loose from the adjacent parts. Breaking the continuity lessens the resisting power of the revetment, since the torn edges are attacked and gradually destroyed under conditions which are not present so long as the bond is unbroken.

At first this sloughing was looked upon as something mysterious and was dreaded accordingly. Later, its cause was recognized in the efflux of ground water, but even then its nature was misapprehended. Efforts were made to meet the difficulty by drains and buttresses and the most persistent cases met with were conquered by these means, but at considerable cost. It is now seen that the natural bank graded to a slope and surcharged with water behaves precisely as any other earther slope would do. If too steep it will slough, otherwise it will not. If a levee or other artificial embankment will slough at 3 to 1, a graded bank of the same material can not be expected to stand at the same slope. Carrying the analogy further, it may be observed that sloughing rarely reaches the top of a levee and never begins there. A banquette or other support at the bottom of a slough stops it by raising the foot of the slope until it is flattened to the point of stability, while above the slough, the original slope remains, or becomes even steeper in some cases. The evident necessity of a flat and regular grade, especially near low water, points to the desirability of means for making such a grade under water, since in most years the extreme low-water season is too brief to do much work, and in some that stage is not reached at all. It will often be necessary to grade at higher stages and when it is so, it is essential to really good work, that the slope be continued under water to extreme low water, and further, would be better. Some experiments in this direction have been made, but have not been carried far enough to give definite indications. Of course it can be done. It is only a question of cost.

It may be possible to partly offset the increased cost due to increased width of shore-work on a flat slope by making the upper third steeper. This was tried on a small scale at the head of the Daniel's Point work, where the lower slope of 4 to 1 was changed to 3 to 1 above, making the entire width of shore-work 10 feet less than would have been required by an uniform 4 to 1 slope.

In still another direction an effort has been made to narrow the shore work by terminating the grade at its upper edge in a vertical bench of such height as to bring the upper surface of the completed revetment tangent to the top of the bank, instead of the lower surface as formerly. Some further retrenchment in this direction seems feasible.

The real source of stability of a revetted upper bank is in the flat slope given to it. The protective work laid upon it acts only indirectly by preserving the slope from abrasion. The agencies tending to disturb the grade are wave and water-line action and rain wash. The first two are really the same, the abrasion so often observed at the water-line when the river is stationary being caused by minute waves. All these disturbing forces decrease in intensity from extreme low water up, and since the present covering of brush and stone is uniform in strength and is quite sufficient at the bottom where the strain is greatest, it seems probable that it may be replaced near the top by a lighter and cheaper form. Bermuda sod and willow plantations seem most likely to succeed and might well be introduced experimentally in future work, beginning at the top of the slope and extending gradually downward. It is possible that in some cases they might be brought down to the line of continuous vegetation. All the methods indicated, steepening the upper slope and covering to the top with brush, substituting sod or willows for the brush on the upper slope, and leaving a vertical bench of greater or less height at the top of the slope, may be utilized on banks of different materials, to cheapen the work by narrowing the brush covering, which, when carried as far as can safely be done, will give the cheapest efficient protection from low water up that can be devised. It is open to a single objection in the perishable nature of part of its material.

PLANT.

During the past year the plant of the first and second districts has decreased in amount, but is much improved in average condition. Many pieces had been wholly unserviceable for sometime, but had been kept on the papers in the hope that some use might be found for them. It was necessary to remove the fleet from Bullerton Chute, and in doing so it become evident that these pieces could not be moved. An inspection was asked for, as a result of which 9 pile-drivers and 78 miscellaneous pieces were condemned and dropped.

One of the earliest recommendations in connection with the last appropriation, was the construction of a floating dock. It was completed in January, 1889, and has

since been in constant operation. Most of the heavy pieces have been docked and repaired as thoroughly as their condition would justify. By the time another appropriation is available everything except barges will have been on the dock.

In the classes of steam-boats, graders, pile-drivers, quarter-boats and weaving barges, the present plant with slight current repairs should suffice for the expenditure of any allotments likely to be made to the two districts for the next two years. But one set of mooring plant can possibly be used again and that would scarcely be safe under a great strain. These barges, to meet all demands upon them, must endure a variety of strains, both in direction and intensity such as was never contemplated in the present type of barge construction and which no structure in wood, of reasonable cost can stand for any length of time. In substituting wire for manilla-rope in the head lines, the elasticity of the former, which tends in a measure to equalize these strains, is lost. Under the new conditions it is not advisable to build mooring barges of anything but steel, and they should be provided with mechanical appliances for handling the wire cables. They can be used for mooring barges in the present way or as fender barges, should that plan be adopted. In the latter case the strains on the mooring barges will be lessened and some of the present barges will answer.

The number of barges now fit for use is entirely insufficient to carry on operations of any magnitude. The work of the last two seasons would have been impossible but for the general service barges, which the early delivery of the stone made available for use in the districts. Some of these barges are scarcely fit for loading with stone, while amply strong to carry brush. Those, it is probable, will be left to the districts, but even with them there will not be enough, as scarcely a single one of the district barges is fit to load to its full capacity. The demand for riprap stone in large quantities which the works have made for several years past has brought forward a number of quarry owners, steam-boat men and contractors who have offered and delivered stone at various points, and in almost every case at less cost than it could be done by the general service plant. More than half of the stone used under the last appropriation was obtained by contract or by open purchase of outside parties. Of course the knowledge on the part of these people that the Government has the plant ready for use, is an important factor in the maintenance of low prices. It would not be prudent, therefore, to dispense with the plant, but as its use for towing stone will be much less frequent than formerly, it should be divided among the districts, where it can always be used to advantage, when work is in progress and at other times, can be cared for in connection with the local fleets at less cost than as a separate organization.

THE FLOOD OF 1890.

A stage of 40 feet on the Cairo gauge may be taken as the point at which the river in that vicinity ceases to be channel-contained and overflow conditions begin. In 1890 the river at Cairo was above that stage from January 16 to February 1, February 13-20, and February 27 to April 15, a total of seventy-one days. In 1882, the year of the only flood with which this one is comparable the 40-foot stage was passed in ascending on January 15, and in descending April 3, giving a flood period of seventy-eight days as compared with the seventy-one days of the flood of 1890. The relative heights of the latter with respect to 1882 and also to the highest known water at various points in the first and second districts are shown in the following table:

High-water table.

Station.	Distance from Cairo.	Highest known water.		Highest water, 1890.		1890, above or below highest known.	1890, above or below 1882.
		Date.	Gauge.	Date.	Gauge.		
			Feet.		Feet.	Feet.	Feet.
Cairo, Ills	0	Feb. 27, 1883	52.17	Mar. 12	48.80	—3.37	—3.0
Belmont, Mo	21	Feb. 23, 1884	45.80	Apr. 6	43.03	—2.77	—2.4
New Madrid, Mo	69	Feb. 24, 1884	41.52	Mar. 15	38.18	—3.34	—3.09
Cottonwood Point, Mo	123	Feb. 28, 1883	37.85	Mar. 15	36.40	—1.45	—1.1
Fulton, Tenn	175	Mar. 1, 1882	36.69	Mar. 22	34.90	—1.79	—1.7
Memphis, Tenn	232	Mar. 10, 1889	35.30	Mar. 15	35.60	+0.30	+0.4
Mhoen's, Miss	275	Mar. 8, 1883	40.29	Mar. 29	38.50	—1.76	—1.3
Helena, Ark	307	Apr. 30, 1886	48.10	Mar. 29	47.70	—0.40	+0.5
Sunflower, Miss	353	Mar. 10, 1883	41.75	Apr. 1	43.90	+1.15	+1.3

Omitting the record at Memphis, which will be discussed later, it appears from the column of differences that in the first hundred miles below Cairo, the maximum heights of 1890 were 2.77 to 3.37 feet below the highest previously known and 2.47 to 3.09 below those of 1882. In the next 200 miles, the corresponding differences were 1.45 to 1.79 and 1.15 to 1.79 respectively, or roughly, about half of those in the first named section. At Helena the 1890 flood passed above 1882, though still a fraction of a foot below the highest known point, and at Sunflower Landing, 353 miles below Cairo, the flood of 1890 was 1.15 feet the highest on record.

The anomalous elevation at Memphis first appeared in 1886. It is purely local, disappearing a few miles above and below the gauge. Prevailing opinion has assigned as its cause the building of railroad embankments across the St. Francis Basin, of which three are now there, the Kansas City, Little Rock and Iron Mountain. The second of these has been in existence for many years, and can not be used to account for this phenomenon. Advantage was taken of the excellent opportunity offered by the late flood to investigate the effect of these embankments in retarding the swamp wave and returning part of it at and above Memphis. A party was organized and equipped with a leveling apparatus and current meter mounted on a hand car and sent twice over the Kansas City and once over each of the other roads. The relative elevations of water surface above and below the embankment were determined at frequent intervals and the discharge through openings was carefully measured. All the conditions were favorable for close work and the results may be confidently accepted. They are shown in the following table:

St. Francis Basin.

Station.	Date.	Gauge, Memphis.	Area.	Mean velocity feet per second.	Discharge, cubic feet per second.
			Sq. feet.		
Kansas City, Springfield and Memphis Rwy.	Mar. 17, 18, 19	35.60	264,994	1.84	487,536
Do	Mar. 28, 29	35.50	274,020	1.77	484,111
St. Louis, Iron Mountain and Southern Railway	Mar. 21, 22	35.40	498,250	1.16	578,817
Little Rock and Memphis Railway	Apr. 1, 3	35.40	239,551	2.18	501,225

The volume of the swamp wave is shown to have been, in round numbers, 500,000 cubic feet per second. Three of the determinations agree very closely. The fourth one, the Iron Mountain road, is larger by some 20 per cent. This is partly accounted for by heavy local rains just preceding the dates of that measurement, and partly by the low velocities encountered, for which the performance of the meter, an old one and much worn, was far less reliable than in the other cases. The superelevations on the upper sides of the embankments averaged 0.86 foot, 0.44 foot and 0.23 foot for the three roads in the order in which the swamp wave passed them. With a volume of swamp wave fully as great as previous experience would lead us to expect for such a flood, and with such slight disturbance of the normal flood surface in the vicinity of the road-beds, it may safely be concluded that they are not responsible for any appreciable part of the recent abnormal flood-heights at Memphis.

But one other cause can be assigned for this phenomenon, and while the effect is surprisingly large, it may be as well to suspect our preconceived ideas of what it ought to be as to reject the apparent demonstration of what it is. That cause is the recent change in the shape of the river immediately above Memphis. Caving in the bend opposite has progressed until the entire stream is now thrown off from Hopefield Point and projected bodily directly toward the gauge. To escape the *cul-de-sac* the river is compelled to turn an angle of more than 90°, and the force to do this must be represented by a local elevation of surface. Add to this the fact that the changes mentioned have had the effect of placing the Memphis gauge a mile or more nearer Cairo relatively than it was before, and it is believed that the superelevation of recent floods is fully explained as a local disturbance which may be neglected in discussing the general flood profile.

The volume of the flood of this year in the channel of the river was well determined by discharge observations at New Madrid, Plum Point, Memphis, and Helena. The results obtained are here tabulated.

Observed flood discharges, 1890.

NEW MADRID, MISSOURI.

Date.	Gauge.	Area.	Mean velocity feet per second.	Discharge, cubic feet per second.
		Sq. feet.		
Mar. 25	36.6	229,698	5.55	1,329,387
Apr. 8	37.7	246,492	.....	.....
Apr. 10	36.9	240,893	5.29	1,274,319
Apr. 11	36.2	236,028	5.23	1,234,597
Apr. 12	35.6	233,061	5.21	1,214,031
Apr. 14	34.2	226,213	4.75	1,073,586

PLUM POINT REACH.

Location.	Date.	Gauge.	Area.	Mean velocity feet per second.	Discharge, cubic feet per second.
	1890.	*Feet.*	*Sq. feet.*		
Main river	Mar. 7	30.30	144,400	5.28	762,130
Elmot chute	....do ...	30.30	43,960	3.24	142,372
Island 30 chute	....do ...	30.30	33,310	3.39	113,012
Total	.....	.....	221,690	.....	1,017,514
Main river	Mar. 9	30.90	148,720	5.49	816,140
Elmot chute	....do ...	30.90	42,340	3.59	151,824
Island 30 chute	....do ...	30.90	34,564	3.16	109,393
Total	.....	.....	225,624	.....	1,077,357
Main river	Mar. 12	31.66	153,560	5.54	850,348
Elmot chute	....do ...	31.66	45,340	3.57	161,874
Island 30 chute	....do ...	31.66	34,460	3.39	116,868
Total	.....	.....	233,360	.....	1,129,090
Main river	Mar. 15	32.09	152,425	5.76	878,098
Elmot chute	...do ...	32.09	49,615	3.52	174,689
Island 30 chute	....do ...	32.09	36,836	3.19	117,362
Total	.....	.....	238,876	.....	1,170,139

MEMPHIS, TENNESSEE.

Date.	Gauge.	Area.	Mean velocity feet per second.	Discharge, cubic feet per second.
1890.	*Feet.*	*Sq. feet.*		
Mar. 17	35.60	159,632	8.36	1,335,187
Mar. 18	35.50	154,394	8.24	1,272,922
Mar. 20	35.50	153,526	8.76	1,345,637
Mar. 22	35.65	144,792	8.51	1,232,445
Mar. 24	35.58	151,479	8.69	1,315,857
Mar. 25	35.55	152,037	8.50	1,292,028
Mar. 26	35.46	147,637	8.88	1,295,314
Mar. 27	35.40	147,957	8.54	1,263,565
Mar. 29	35.30	152,232	8.46	1,288,566
Mar. 31	35.30	157,725	8.33	1,312,562
Apr. 1	35.38	145,390	8.39	1,204,946

Observed flood discharge, 1890.—Continued.

HELENA, ARKANSAS.

Date.	Gauge.	Area.	Mean velocity feet per second.	Discharge, cubic feet per second.	Discharge over bank.
1890.	*Feet.*	*Sq. feet.*			
Apr. 3	47.42	242,611	6.38	1,547,348	*37,370
Apr. 4	47.40	246,875	6.36	1,570,004	.....
Apr. 5	47.31	236,125	6.36	1,500,843	.....
Apr. 7	47.16	256,315	6.18	1,460,675	†11,205
Apr. 9	47.05	231,200	6.05	1,398,355	.....
Apr. 10	47.03	238,800	5.96	1,405,100	.....
Apr. 12	47.08	235,565	6.13	1,443,430	.....
Apr. 14	47.20	233,000	6.29	1,466,466	.....
Apr. 16	47.40	237,418	6.23	1,497,360	.....
Apr. 17	47.46	238,220	6.38	1,519,374	.....
Apr. 18	47.31	238,720	6.23	1,487,103	.....
Apr. 19	47.00	228,890	6.43	1,471,400	.....
Apr. 21	46.00	230,840	5.92	1,367,641	.....
Apr. 23	44.48	224,090	5.66	1,269,101	.....

*Austin crevasse. †Louisville, New Orleans and Texas Railway.

From the foregoing data a comparison of the volume of the last flood with that of 1882 at New Madrid 75, Fulton 175, Memphis 232, and Helena 307 miles below Cairo, may be made with a fair degree of satisfaction. At New Madrid the highest observed discharge was 1,329,000 cubic feet per second for a stage of 36.6 preceding the maximum which was 38.18 feet or 1.58 feet above the stage of observation. In 1888–'89 a series of discharges were measured at the same section from which the form of the velocity curve is known. Knowing the rate of increase of both area and velocity, the discharge at the highest stage may be approximately determined from this lower observation and is found to be 1,412,500 cubic feet per second. The nearest discharge station in 1882 was at Columbus, 55 miles above this. There is no tributary between them and the escape over the west bank is all or nearly all returned at New Madrid. A direct comparison of New Madrid in 1890 with Columbus in 1882 will not introduce serious error. The maximum discharge of 1882 at Columbus was 1,603,000 cubic feet per second, being greater than the New Madrid discharge of this year by 190,500 cubic feet per second or scant 12 per cent., which is the excess in volume of the flood of 1882 over that of 1890 in this vicinity. Any error which may have been introduced by the direct comparison of New Madrid and Columbus, would tend to reduce this percentage of excess, or in other words to make the flood of 1890 appear relatively larger.

The observed discharges at Plum Point were on a section 15 miles above Fulton, where a permanent gauge is maintained and where discharge measurements have been made on several occasions, so that the velocity curve is well known. From the Plum Point section to Fulton there are levees or high ground on both sides of the river except for a distance of 4 miles on the east side, where a small stream known as Cold Creek debouches. This creek is supplied by water escaping from the Mississippi between Ashport and the hills, and which goes around the discharge section at Plum Point. The discharge of Cold Creek has been measured several times and may be safely taken at 25,000 cubic feet per second. Adding this to the maximum observed at Plum Point, 1,160,000, the sum 1,185,000 should be the discharge at Fulton at the same stage, which was 34.53 feet on the Fulton gauge. The maximum reading of this year at Fulton was 34.90, being 0.37 foot above the stage corresponding to this determined discharge. The increase in discharge at this stage is 37,500 cubic feet per second for 1 foot of rise on the gauge, so that 1,200,000 cubic feet per second is the approximate maximum discharge of 1890 at Fulton. In 1880 a complete series of observations at this place gave a discharge curve extending from low water to within 2 feet of extreme high water, and from this curve the probable maximum discharge of 1882, at a stage of 36.69 feet as published in the report of the Commission for 1883, was 1,288,000 cubic feet per second, or 88,000 cubic feet per second more than in 1890, giving a trifle less than 6 per cent. as the excess of the flood of 1882 over that of 1890 at this point.

At Memphis the discharge at maximum stage was measured at 1,335,000 cubic feet per second. A discharge curve for this place has also been determined from an extended series of observations at Hampton, a few miles below, and from it the maximum discharge of 1882 at 35.2 on the Memphis gauge, as published in the report of 1883, was 1,188,000 cubic feet per second. By this showing the flood of 1890 had a maxi-

mum discharge in the channel exceeding that of 1882 by 147,000 cubic feet per second, or about 12¼ per cent.

The aggregate discharge across the parallel of Memphis is obtained by adding to the channel discharge the volume of the swamp wave. The former is 1,335,000 and the latter 500,000, giving a total of 1,835,000 cubic feet per second as the maximum discharge in 1890 over an east and west line through Memphis. A corresponding quantity for 1882, though far less exact, will afford an interesting comparison. In that year the escape into the St. Francis Basin was measured but at stages somewhat below the maximum. An attempt was made to estimate for the maximum stage, and it is believed to have been fairly successful, though several arbitrary assumptions had to be made. The result obtained was a probable maximum escape of 611,000 cubic feet per second above Memphis. Adding to this the estimated channel discharge of 1882 at Memphis, as given above, there results 1,799,000 cubic feet per second as the greatest discharge across the parallel of Memphis in 1882, being less by 36,000 cubic feet than the corresponding quantity in 1890. This, though a far from reliable determination, will be allowed to offset in part the deduction for the comparison of channel discharges and the conclusion, if reached, that the floods of 1882 and 1890 at Memphis were practically identical in maximum volume. Both determinations include the discharge of the St. Francis River, supposed to be equal in the two years.

At Helena we have the first direct comparison of actually observed channel discharges in the two floods under consideration. The observed maxima were, in 1882 1,558,000 cubic feet per second, gauge 47.10 feet, and in 1890 1,570,000 cubic feet per second, gauge 47.42 feet, the volume in 1890 exceeding that in 1882 by 12,000 cubic feet per second. The channel discharge at Helena plus the discharge of Austin Crevasse, and that over the bank on the discharge section, gives a total of 1,617,000 as the maximum discharge past Helena, supposing the entire flood to have been concentrated at that point. This, in other words, is the maximum discharge of the flood of 1890 in complete restraint. In 1882 the escape into the Yazoo Basin, between Memphis and Helena, was measured at 290,000 cubic feet per second. This, added to the observed discharge of that year, gives 1,848,000 cubic feet per second as the maximum discharge of that year across the parallel of Helena, a result closely in accord with that obtained at Memphis.

To more clearly show the significance of the foregoing figures, they are grouped in the following table:

Maximum discharge in cubic feet per second.

Locality.	Distance from Cairo.	Flood of 1882.			Flood of 1890.			Differences.*
		In the channel.	Out of the channel.	Total.	In the channel.	Out of the channel.	Total.	
	Miles.							
New Madrid	75	1,603,000	.....	1,603,000	1,412,500	.....	1,412,500	+190,500
Fulton	175	1,288,000	(†)	.....	1,200,000	(†)	.....	+ 88,000
Memphis	232	1,188,000	611,000	1,799,000	1,335,000	500,000	1,835,000	— 36,000
Helena	307	1,558,000	290,000	1,848,000	1,570,000	47,000	1,617,000	+231,000

* +82 greater than 90; —90 greater than 82. † Not determined.

The above table completely analyzes and compares the floods of 1882 and 1890 along the St. Francis front, the only part of the river where such a comparison can be made, because the only part where the conditions were essentially the same in the two years. It shows that the latter flood entered the upper end of the main trunk of the river with a maximum volume 190,500 cubic feet per second less than the former; that at Fulton (assuming that the discharges outside the channel were the same in the two years) this difference was reduced to 88,000 cubic feet; that at Memphis the total maximum discharge per second in 1890 exceeded by 36,000 cubic feet that in 1882, and that on the parallel of Helena the maximum discharge of 1882 was again in excess by the very large amount of 231,000 cubic feet per second. The two floods are also seen to have been very similar in all the features of the distribution of flow as between the channel and the swamp, and also in the different parts of the channel. The conclusion can not be resisted that the flood of 1890 was on the parallel of Memphis, the complete counterpart of the flood of 1882.

Between Memphis and Helena, on the other hand, the table shows that a remarkable change took place in the particular factor of flood regimen which is under consideration, the maximum discharge amounting to a relative difference in the two years of 267,000 cubic feet per second. In 1882, an unrestrained flood, having, on the

parallel of Memphis, a maximum discharge of 1,799,000 cubic feet per second, gave, on the parallel of Helena, 70 miles below, where it was also unrestrained, a maximum discharge in channel and swamp at 1,848,000 cubic feet per second. In 1890 a flood identical in all its features with that of 1882 on the parallel of Memphis, but gradually confined to the channel between there and Helena, passed the latter point entirely in the channel with a maximum discharge less by 231,000 cubic feet per second than that of 1882.

It has been the usual if not universal practice for engineers investigating the subject, to assume that floods of equal magnitude must have the same maximum discharge whether restrained or not. In considering the question of height of embankments to restrain a flood of known magnitude the aggregate maximum discharge in channel and swamp has been assumed as the maximum to be passed between the levees. From a known relation of gauge and discharge for an unrestrained flood, the surface height necessary to pass this assumed maximum has been deduced, and the enormous resulting elevations have been the perpetual nightmare of levee enterprise. If the experience of this year at Memphis and Helena means anything, it is that that method of deduction and the results obtained by it are radically wrong. The relative magnitudes of floods can not be gauged by the maximum discharges at a given point, unless the conditions of restraint are essentially the same. A flood confined to the channel will have a less maximum discharge than the same flood without restraint, and so far as this single determination may be relied upon quantitively, the maximum discharge of a flood confined to the channel will be but little greater than the maximum discharge in the channel of the same or an equivalent flood unrestrained.

The question of restraint of a great stream like the Mississippi River usually presents itself to the mind with most vividness at the time when its need is most apparent, or when an instant flood is in its full career of devastation. Though illogical, it is perhaps natural that the problem should take a form like this. What would be the effect of suddenly squeezing this vast expanse of water up between two parallel walls 5,000 or 6,000 feet apart? The answer is at hand without argument or question. It would be to raise the surface to a height so great that is is useless to speculate upon its exact measurement.

The circumstances under which restraint should be viewed theoretically are those under which it is an engineering possibility. The barriers can only be erected when the water is absent, and the rising river, as its surface attains the level of the natural banks, will find the wall in place and the low country behind it dry. The river will then be under the new conditions from this moment until the rise has culminated, and these new conditions, antecedent to the maximum at the flood, must enter largely in determining the amount of that maximum. How largely and in what direction, it is believed the above data constitute a demonstration.

Onto a flood past Helena fully equal to that of 1882 was discharged a very large volume of water from White and Arkansas rivers. White River especially contributed very much more water than it has ever been known to do, so far as may be judged by the number of flood waves and their heights in the valley proper of that stream. The levee at Laconia Circle, near the confluence of the Mississippi and White, was first broken by the wave wash of a series of wind-storms, and finally overwhelmed by a flood which rose 2 feet higher than any previous record. Aside from this, the only break in the first and second districts was a small one in the Upper Mississippi district at Austin, 288 miles below Cairo, which broke April 3. It did not enlarge after first observed, and its discharge was measured at 37,370 cubic feet per second the day after it broke. The cause of the break was a seep hole in the ground under the levee, which suddenly broke out while operations were in progress to stop it.

The levees on Plum Point Reach and on the White River Front near Helena were patrolled and guarded by United States employés during the entire flood period. Prompt measures were taken to protect places injured or likely to be so. All damage resulted from wave wash on the front slope, and was met by revetments of sacks filled with earth and bagging, held in place by stakes or sacks. At Helena the brunt of the fight was made by the local levee board. An assistant engineer was constantly on the ground, but they left him very little to do. No attention was paid in these districts to the Mississippi levees, which were attended to exclusively by the State authorities.

A comparison of the grade of the Mississippi levees above White River shows that in the decade 1880–1890 they have been raised as follows: At the upper end of the line at Horn Lake, 2 feet, increasing gradually to 3½ feet opposite the St. Francis River, decreasing to 2½ feet near Friar's Point, and again increasing to 3 feet at the lower end of the outside line opposite Island 66. From above Hushpuckena to the Coahoma-Bolivar line the increase has averaged 2½ feet.

The back line has been extended northward in the same period a distance of 9 miles, with a grade of 1½ feet above high water of 1882 at Hushpuckana. Continuous escape of water between the two lines through Lewis swamp is absolutely prevented.

From 2 feet near the Coahoma-Bolivar line the raise of grade has gradually increased to 3½ feet opposite the mouth of White River.

As in the case of the first district, for the same reason and from the same data, an estimate of 3,500,000 tons per annum is made as the total volume of traffic through the whole or parts of the second district. A statement of the tonnage of the port of Memphis from official sources is appended.

EXHIBITS.

There are submitted with this report a map of Helena Harbor, showing amount and location of work done and to be done; a financial statement and general balance sheet for all allotments to the second district; a statement of disbursements from these allotments classified as to the manner of making them, as required by law; abstracts of proposals in cases of expenditures by formal contract; itemized statements of expenditures on various works; a table of value of plant second district, and a list of civilian engineers employed during the year in the first and second districts.

Very respectfully, your obedient servant,

SMITH S. LEACH,
Captain of Engineers.

Gen. C. B. COMSTOCK,
President Mississippi River Commission.

APPROPRIATION FOR IMPROVING MISSISSIPPI RIVER, SECOND DISTRICT.

Money statement.

June 1, 1889, balance available		$97,576.23
October 12, 1888, amount allotted by Board of District officers for protection of levees, second district	$5,000.00	
June 5, 1889, amount allotted by Mississippi River Commission for Memphis Reach	20,000.00	
March 22, 1890, amount transferred from allotment for Plum Point Reach to protection of levees, second district	2,500.00	
		27,500.00
Total		125,076.23
November 11, 1889, amount expended by general service on account Helena, Ark	10,393.17	
March 18, 1890, amount tranaferred from allotment for Memphis Reach to protection of levees, fourth district	20,000.00	
June 30, 1890, amount expended from June 1, 1889, to date, exclusive of liabilities outstanding June 1, 1889	65,831.18	
June 30, 1890, outstanding liabilities	208.10	
		96,432.45
June 30, 1890, balance available		28,643.78
Amount that can be profitably expended in fiscal year ending June 30, 1892 Submitted in compliance with requirements of sections 2 of river and harbor acts of 1866 and 1867.		750,000.00

General balance sheet.

MEMPHIS REACH.

1889.			1890.		
June 1	To balance, including estimated liabilities	$22,866.24	Mar. 18	By amount transferred to protection of levees, fourth district	$20,000.00
June 5	To amount allotted by Mississippi River Commission	20,000.00	June 30	By amount expended to date	6,687.57
				By liabilities	2.00
				By balance	16,176.67
		42,866.24			42,866.24

General balance sheet—Continued.

MEMPHIS HARBOR.

1889. June 1	To balance	$14,833.75	1890. June 30	By amount expended to date	$9,214.01
				By liabilities	71.10
				By balance	5,548.64
		14,833.75			14,833.75

LEVEES, WHITE RIVER FRONT.

1889. June 1	To balance	$3,954.35	1890. June 30	By balance	$3,954.35

FIRST LEVEE DISTRICT, MISSISSIPPI.

1889. June 1	To balance	$7,677.84	1890. June 30	By amount expended to date	$7,167.76
				By balance	510.08
		7,677.84			7,677.84

OBSERVATIONS AND DISCHARGES, SECOND DISTRICT.

1889. June 1	To balance, including estimated liabilities	$783.32	1890. June 30	By amount expended to date	$781.25
				By balance	2.07
		783.32			783.32

GAUGES, SECOND DISTRICT.

1889. June 1	To balance, including estimated liabilities	$822.50	1890. June 30	By amount expended to date	$540.00
				By liabilities	135.00
				To balance	147.50
		822.50			822.50

SURVEY AND EXAMINATIONS, SECOND DISTRICT.

1889. June 1	To balance	$2,913.96	1890. June 30	By amount expended to date	$1,338.90
				By balance	1,575.06
		2,913.96			2,913.96

HELENA, ARKANSAS.

1889. June 1	To balance, including estimated liabilities	$72,251.11	1890. June 30	By amount expended to date	$61,855.14
				By amount expended by general service to date	10,393.17
				By balance	2.80
		72,251.11			72,251.11

General balance sheet—Continued.

PROTECTION OF LEVEES, SECOND DISTRICT.

1888. Oct. 12	To amount allotted by Board of District Officers.	$5,000.00	1890. June 30	By amount expended to date	$1,595.55
1890. Mar. 22	To amount transferred from allotment for Plum Point Reach	$2,500.00		To balance	5,904.45
		7,500.00			7,500.00

APPROPRIATION FOR IMPROVING MISSISSIPPI RIVER, FIRST AND SECOND DISTRICTS.

Money statement.

June 1, 1889, balance available		$1,779.80
June 5, 1889, amount alloted by Mississippi River Commission for care of plant, first and second districts		60,000.00
Total		61,779.80
June 30, 1889, amount expended from June 1, 1889, to date, exclusive of liabilities outstanding June 1, 1889	$40,072.35	
June 30, 1889, outstanding liabilities	2,705.08	
		42,771.43
June 30, 1890, balance available		19,002.37
Amount that can be profitably expended in fiscal year ending June 30, 1892 Submitted in compliance with requirements of sections 2 of river and harbor acts of 1866 and 1867.		70,000.00

General balance sheet.

CARE OF PLANT, FIRST AND SECOND DISTRICTS.

1889. June 5	To amount allotted by Mississippi River Commission	$60,000.00	1890. June 30	By amount expended to date	$39,547.85
				By liabilities	2,705.08
				By balance	17,747.07
		60,000.00			60,000.00

SURVEYS, FIRST AND SECOND DISTRICTS.

1889. June 1	To balance, including estimated liabilities	$2,029.80	1890. June 30	By amount expended to date	$774.50
				By balance	1,255.30
		2,029.80			2,029.80

SECOND DISTRICT.

Disbursements made under appropriations for improving Mississippi River; acts of August 5, 1886, and August 11, 1888.

[June 1, 1889, to June 1, 1890.]

Contracts made with—	For what made—	Disbursements under contract.	Liabilities under contract.	Total.
Hunter & Frey	Willow brush and poles	$7,825.59		$7,825.59
Fudge & Kearns (balance)*	Levee work	6,774.93		6,774.93
		14,600.52		14,600.52

*Part payment reported in 1889.

Disbursements made otherwise than under contract.

For what expended.	By public notice and sealed proposals.	In open market.	Liabilities.	Total.
Material and supplies	$14,342.06	$6,652.05	.....	$20,994.11
Subsistence	3,815.37	2,510.85	.....	6,326.22
Services	.....	41,270.74	$90.00	41,360.74
Tools and appliances	434.73	4,644.81	.....	5,079.54
Miscellaneous	.....	595.94	.....	595.94
	18,592.66	55,673.89	90.00	74,356.55

FIRST AND SECOND DISTRICTS.

[June 1, 1889, to June 1, 1890.]

Disbursements made otherwise than under contract.

For what expended.	By public notice and sealed proposals.	In open market.	Liabilities.	Total.
Material and supplies	.....	$233.12	.....	$233.12
Subsistence	.....	86.50	.....	86.50
Services	.....	35,306.24	$3,500.00	38,806.24
Tools and appliances	.....	27.50	.....	27.50
Miscellaneous	.....	364.66	.....	364.66
	.....	36,018.02	3,500.00	39,518.02

Abstract of proposals for furnishing willow brush, and poles at Helena, Arkansas, received in response to advertisement dated June 20, 1889, by Captain Smith S. Leach, Corps of Engineers.

No.	Name and address of bidder.	10,000 cords of willow brush.	2,000 cords of willow poles.	Total.
		Per cord.	*Per cord.*	
1	A. C. Terrell, Memphis, Tenn	$1.20	$1.62½	$15,250.00
2	Joseph Evins, Dardanalle, Ark	1.19	1.50	14,900.00
3	Elisha Evans, Memphis, Tenn	1.04	1.65	13,700.00
4	L. A. Fitzpatrick, Helena, Ark	1.20	1.75	15,500.00
5	Hunter & Frey, Memphis, Tenn	*.90	*1.47	*11,940.00
6	Nathan W. Tucker, St. Louis, Mo	(†)	(†)	(†)

*Accepted. †No prices stated in proposals.

Statement of expenses for work done at Helena, Arkansas, from August 21, 1889, to February 1, 1890.

Items.	Administration.	Care of plant.		General repairs.		Steamers.		River mattress.		Crib-dikes.		Embankment.		Unloading stone.	Total.		Percentage.
	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	Amt.	Cost.	Cost.	Amt.	Cost.	
Labor	$2,448.25	.....	$2 033.58	.....	$1,201.48	.....	$1,791.50	.....	$8,734.09	.....	$5,722.42	.....	$1,135.41	$182.40	.....	$23,249.13	41.57
Subsistence services	72.35	.....	239.36	.....	75.79	.....	206.33	.....	579.59	.....	390.36	.....	54.41	.....	.....	1,618.19	2.89
Subsistence stores	219.72	.....	780.93	.....	285.12	.....	354.10	.....	2,354.02	.....	1,530.93	.....	247.94	.....	.....	5,752.76	10.29
Brush, cords	.....	.....	.....	.....	.....	.....	.....	4,201	3,780.90	1,822	1,639.80	.....	.....	.....	6,023	5,420.70	9.69
Poles, do	.....	.....	.....	.....	.....	.....	.....	631	933.58	482	718.36	.....	.....	.....	1,113	1,652.24	2.96
Piles, feet	.....	.....	.....	.....	.....	.....	.....	2,080	135.50	1,040	104.00	.....	.....	.....	3,120	239.50	0.43
Stone, cubic yards	.....	.....	.....	.....	.....	.....	.....	3,400	6,600.26	1,818	3,529.19	726	1,409.34	.....	5,944	11,538.79	20.63
Wire, pounds	.....	.....	.....	.....	.....	.....	.....	45,301	1,232.63	28,320	787.32	.....	.....	.....	73,621	2,019.95	3.62
Wire strands, do	.....	.....	.....	.....	.....	.....	.....	6,780	258.70	3,146	138.51	.....	.....	.....	9,926	397.21	0.71
Iron, do	.....	.....	.....	1,867	48.71	16	40	2,353	59.31	3,221	77.58	.....	.....	.....	7,457	185.95	0.33
Spikes, do	.....	.....	.....	.....	.....	.....	.....	4,230	105.85	4,084	102.70	.....	.....	.....	8,314	208.55	0.37
Nails, do	.....	.....	.....	600	15.00	.....	.....	.....	.....	400	10.00	100	2.50	.....	1,100	27.50	0.05
Coal, boxes	.....	485	165.12	430	147.75	3,179	1,080.13	195	62.88	70	23.75	.....	.....	.....	4,959	1,479.63	2.65
Lumber, feet	.....	.....	.....	14,159	212.34	299	5.23	3,222	46.71	56,678	555.66	7,400	51.80	.....	81,758	871.74	1.56
Manilla rope, pounds	.....	.....	.....	.....	.....	.....	.....	2,950	390.90	2,190	284.70	.....	.....	.....	5,140	675.66	1.21
Gravel, cubic yards	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	79	23.70	.....	79	23.70	0.04
Oakum, pounds	.....	.....	.....	75	6.08	.....	.....	.....	.....	.....	.....	.....	.....	.....	75	6.08	0.01
Paints	.....	.....	.....	.....	10.56	.....	8.82	.....	.....	.....	.....	.....	.....	.....	.....	19.38	0.03
Oils and engineers' supplies	.....	.....	70.12	.....	15.42	.....	61.96	.....	.62	.....	1.72	.....	.....	.....	.....	149.84	0.27
Miscellaneous	116.44	.....	95.60	.....	24.23	.....	55.20	.....	48.72	.....	40.25	.....	7.12	.....	.....	387.56	0.69
Total	2,856.76	.....	3,384.71	.....	2,022.48	.....	3,563.67	.....	25,324.62	.....	15,657.20	.....	2,932.22	182.40	.....	55,924.06	.....
Percentage	5.11	.....	6.05	.....	3.62	.....	6.37	.....	45.28	.....	28.00	.....	5.25	0.32	.....	.....	100.00
Work done	.....	.....	.....	.....	.....	9 mats = 6,493 squares made ... 7 mats = 5,180 squares covered.. 2 mats = 1,313 squares lost		.....	.....	7 cribs = 355,672 cubic feet.		51,868 cubic feet and 1,495 square yards of paving.		2,125 cubic yards.	.....	.....	.....
Cost per unit	.....	.....	.....	.....	.....	$3.90 per square made. $4.89 per square covered.		.....	.....	$0.044 per cubic foot.		$0.0565 per cubic foot.		$0.086 per cubic yard.	.....	.....	.....

SECOND DISTRICT, IMPROVING MISSISSIPPI RIVER, MEMPHIS HARBOR.

Itemized statement of expenditures for repairs of dikes.

Items.	Office and general administration.	Dikes.			Total.
		Gravel and stone.		Earthwork.	
		Quantity.	*Price.*		
Labor	$450.00	.....	$992.95	.....	$1,442.95
Stone	.....	3,582 yds	6,553.70	.....	6,553.70
Gravel	.....	983½ yds	295.00	.....	295.00
Earthwork	.....	9,128 yds	.....	$3,002.43	3,002.43
Lumber	.....	.....	20.10	.....	20.10
Rope	.....	387 lbs	52.25	.....	52.25
Tools and appliances	.....	.....	34.00	.....	34.00
Towing	.....	.....	31.00	.....	31.00
Miscellaneous	72.00	.....	4.45	.....	76.45
Total	522.00	.....	7,983.45	3,002.43	11,507.88

Approximate value of plant belonging to the United States and used upon the improvement of the Mississippi River, second district.

Class of property.	No.	Approximate value May 31, 1890.	Class of property.	No.	Approximate value May 31, 1890.
Steamer *H. M. Graham*	1	$2,671	Barges	23	$10,675
Launch *Dauphin*	1	560	Skiffs	26	200
Flat-boats	2	326	Tools and appliances	....	1,882
Mattress boats	2	4,192	Office furniture	....	180
Machine boat	1	2,569	Surveying instruments	....	105
Mooring barges	4	1,918			
Quarter-boats	5	2,903	Total	....	38,090
Pile-drivers	9	9,909			

List of civilian engineers employed on work of improving Mississippi River, first and second districts, in charge of Capt. Smith S. Leach, Corps of Engineers, from June 1, 1889, to May 31, 1890, under river and harbor appropriation acts, approved August 5, 1886, and August 11, 1888.

Name and place of residence.	Time employed.	Compensation per month.	Where employed.	Work on which employed.
	M. D.			
Aug. J. Nolty, Chattanooga, Tenn.	12	$150	Plum Point Reach	Improving Mississippi River, Plum Point Reach.
W. M. Rees, Memphis, Tenn.	2	175	Memphis, Tenn	Improving Mississippi River, Memphis Reach.
	9	200	Memphis and Helena	Improving Mississippi River, Memphis Reach and Helena, Ark.
Chas. W. Stewart, Champaign, Ill.	2	120	Plum Point Reach	Surveys.
	4	140	Hickman, Ky	Improving Mississippi River, Hickman, Ky.
	4	140	Columbus, Ky	Improving Mississippi River, Columbus, Ky.
	2	140	Helena, Ark	Protection of levees, second district.
Wm. Gerig, Columbia, Mo	3 24	130	New Madrid, Mo	Observations and discharges, first district.
	4	130	Memphis, Tenn	Improving Mississippi River, Memphis Harbor.
	3	130	....do	Observations and discharges, second district.
	1 6	130	....do	Surveys and examinations, second district.

List of civilian engineers employed on work of improving Mississippi River, etc.—Continued.

Name and place of residence.	Time employed.	Compensation per month.	Where employed.	Work on which employed.
	M. D.			
C. W. Sturtevant, Appleton City, Mo.	7	$120	Plum Point Reach....	Surveys.
	3	120	Memphis, Tenn.....	Do.
	2	130	Helena, Ark	Observations and discharges, second district.
S. Elliott Moore, Memphis, Tenn.	3 26	150	Memphis, Tenn	Survey of St. Francis Front.
	1 21	140	Buke's Landing, Miss..	Levee inspector.
T. G. Dabney, Clarksdale, Miss.	8½	120	....do	Do.
Eugene L. Harman, St. Louis, Mo.	25	130	New Madrid, Mo.....	Surveys and examinations, first district.

Commerce, by river, of the city of Memphis, Tennessee, during the year ending December 31, 1889, *as reported by the Merchants' and Cotton Exchanges.*

Articles.	Imports.	Exports.	Articles.	Imports.	Exports.
	Tons.	*Tons.*		*Tons.*	*Tons.*
Apples	490	636	Hay	425	11,317
Bran	593	1,265	Hats and caps	3	56
Beans and peas	66	869	Live stock	581	4,612
Butter	20	18	Lard	151	304
Bagging	3,668	1,091	Lumber	370	1,550
Bacon	987	1,255	Liquors	93	252
Boots and shoes	53	552	Lime	20	464
Coal*	125,000	.....	Meal	1,552	1,849
Corn	598	5,409	Molasses	1,919	2,004
Cotton†	31,110	9,322	Nails	2,368	1,020
Cotton-seed	46,852	.....	Oats	107	4,388
Cotton-seed meal	105	.....	Onions	280	163
Cotton-seed oil	11,056	5,951	Potatoes	1,214	1,219
Cotton-seed oil cake	.....	23,869	Pork	90	3,841
Cotton-ties	75	626	Rice	15	237
Cheese	6	136	Sugar	3,714	1,413
Coffee	163	509	Tobacco	38	249
Cement	1,079	392	Wheat	30	38
Dry goods	1,003	1,325			
Eggs	16	17	Total	275,778	93,896
Flour	9,858	6,208			

* For two months ending May 31, 1890. † For twelve months ending May 29, 1890.

APPENDIX H.

REPORT OF CAPTAIN WILLARD YOUNG, CORPS OF ENGINEERS, UPON OPERATIONS IN THE THIRD DISTRICT.

UNITED STATES ENGINEER OFFICE,
Memphis, Tenn., June 2, 1890.

GENERAL: I have the honor to submit the following report of operations in the third district, improving Mississippi River, for the year ending May 31, 1890:

The district was in charge of Capt. William T. Rossell, Corps of Engineers, from June 1, 1889, to November 2, 1889; Capt. Smith S. Leach, Corps of Engineers, from November 2, 1889, to December 21, 1889; Capt. Willard Young, Corps of Engineers, from December 21, 1889, to May 31, 1890.

The third district extends from the mouth of White River, Arkansas, to Warrenton, Miss., a distance of 220 miles. The improvements within the district consist of those works undertaken for the general improvement of the channel, and, besides, those of a local character intended for a special purpose.

The improvements at Lake Bolivar and at Greenville and Vicksburg harbors are of

the latter class. The former class comprises the works of surveys, examinations, observations, etc., intended for the collecting of general data; of levee building, repair, and protection; and more especially of bank protection and channel contraction works.

The operations for the year, in carrying on the various works, will be noted in order.

LAKE PROVIDENCE REACH.

The works of bank protection and channel contraction already begun in the third district for general channel improvement are all comprised within the Lake Providence Reach, which extends from Carolina Landing, Miss., to the foot of Island No. 95, a distance of 35 miles.

The physical characteristics of this portion of the river prior to improvement, the methods employed and the work done in improving the channel up to the year 1889, and the then condition of the river and of the several works of improvement, are described in the reports of the Commission for previous years.

The operations for the year ending May 31, 1890, were confined to bank-protection work at Louisiana Bend.

Preliminary work was commenced June 1 under the direction of Mr. E. C. Tollinger, assistant engineer; on June 19 the charge of the work was given to Mr. H. St. L. Coppee, assistant engineer.

He was relieved by Mr. Arthur Hider, assistant engineer, on August 20, who remained in charge till the close of operations December 31.

The details of the whole season's operations are given in the following report of Assistant Engineer Hider.

The revetting of the bank actually above water consisted of a continuous pavement of stone, laid by hand, and about 10 inches thick.

The revetments above water heretofore constructed at this and other points on the river have consisted of willow mattresses, over which stone has been scattered more or less thickly by hand. The new continuous stone pavement costs from two to four times as much as the old style willow and stone revetment, depending upon the amount of stone used in the latter.

The pavement above water is, however, but a small part of whole revetment, and the extra cost of the continuous stone-work is thought to be more than justified on account of its greater permanency and stability.

Bank protection is the foundation, and, I might say, almost the whole structure, upon which the success of channel improvement work depends. Without it no adequate results can possibly be obtained. With banks properly and permanently protected it will be possible to secure and forever maintain in this reach, and throughout the third district, a channel of ample depth for all the needs of commerce.

REPORT OF MR. ARTHUR HIDER, ASSISTANT ENGINEER, ON OPERATIONS IN LAKE PROVIDENCE REACH FOR THE YEAR ENDING MAY 31, 1890.

Work was begun in June revetting this bend, in accordance with the plans adopted by the Commission, which consisted in the construction of a wide mattress extending out from the low-water line, grading the upper bank to a regular slope, and revetting it from the zero line to the top with riprap.

During June little progress was made in mat-building; 25 feet of mat No. 1, which was 260 feet wide, had been built at the end of the month. In July, 1,027 linear feet of mat was constructed, the lower 727 feet being increased to 300 feet in width on account of the deep water.

In the beginning of August mat No. 1 was completed and the upper 900 feet sunk in place; the building was continued, the lower end still floating on the surface, until a length of 1,315 feet had been reached, when this part was sunk.

In sinking this lower end, the mat broke nearly across the entire width, about 800 feet below the head, and the outer edge buckled, lapping over towards the middle; the water was here about 70 feet deep.

The mat not being well secured to the shore, floated out from the bank; with the aid of a steam-boat it was sunk to the bottom after a good deal of trouble, and in a very unsatisfactory shape.

Mat No. 2, 1,000 by 342 feet, was built and sunk on August 23. On August 24 I as-

sumed charge of the work, relieving Assistant Engineer Coppée, under whose direction the work had been organized and carried on.

Work was at once begun in the construction of mat No. 3. At the end of August there had been built of—

	Feet.
Main mat	565 by 342
Shore mat No. 1	180 by 50
Shore mat No. 2	180 by 75
Shore mat No. 3	104 by 75

These were built to cover the space between mat No. 1 and the shore. In September the mats built were:

	Feet.
Main mat	1,145 by 342
Shore mat No. 4	619 by 171
Shore mat No. 5	380 by 145

The shore mats were to cover the bottom between the edge of main mat No. 1, which slipped out as the bank was being graded, and the shore.

There was constructed—

	Feet.
In October:	
Main mat	1,450 by 342
Pocket mat (6)	300 by 145
In November:	
Main mat	340 by 345
Shore mat No. 7	381 by 150
Shore mat No. 8	310 by 345
Shore mat No. 9	1,047 by 111

The shore mats Nos. 7 and 9 were built so as to overlap the main mattress, which thus made the revetment continuous above the water, as the river was rising rapidly.

Shore mat No. 8 was constructed to protect the foot of the slope, which had cracked and slipped down, due to the fault in sinking mat No. 1. During December shore mat (10), 1,067 by 128 feet, was constructed overlapping the main mat, and continues up the slope, which had only been partially graded; on account of the river rising so rapidly after the completion of the main mattress, there was insufficient time to do this grading.

The total length of bank covered was 6,024 linear feet, the overlapping of the mattress, one on the other, not being included.

The usual method of mattress construction was followed in building these large mats, which are perhaps the widest yet attempted on the river for revetment purposes; the only change was in giving additional strength by weaving in seven-eighths inch wire cables longitudinally through the mat, spaced every 16 feet, and placing holding in cables, extending entirely across the mat at the same distance apart.

These were pulled taut with a pair of tackle-blocks, after the upper slope had been graded, and securely fastened to dead men or trees on the top of the bank to prevent slipping out of the main mattress should a cave take place.

As instructed, the grading of the upper bank was done after the mattress had been sunk in place to a slope carrying from 1 on 3 to 1 on 5, depending on the inequalities of the shore-line, which at many points was indented by large pockets, due to caving.

This slope was afterwards covered with stone, laid by hand, of an average depth of about 10 inches, extending from the low-water line up to the top of the bank.

In this connection it may be interesting to note some of the difficulties encountered in executing the work.

As to mat sinking.—In sinking the first mat, which was done before I took charge, a great deal of difficulty was experienced.

The mat was constructed with its inner edge held out to the zero line by a row of piles driven along the shore; the upper 900 feet was sunk first, and while this part was in place on the bottom the building was continued by adding on to the lower end.

In sinking this, the excessive strain brought on the part reaching from the bottom to the surface of the water while the mat was being lengthened, and the unequal strain due to the rock thrown from barges on this part of the mat, added to the pressure of the current against the long slope, which it would necessarily assume in 70 feet of water, broke the mat, and the fact of but few holding-in cables being used, the mat floated out from the shore before it could be sunk to the bottom, the outer edge rising and buckling; the twisting of the mat causing the rock on the lower end to slide toward the middle.

The method of continuous building and sinking mats of these dimensions can not be recommended.

For mats of much smaller width, from experience gained several years ago, this plan was abandoned, as attended with a great risk of injury and danger of loss.

The plan heretofore followed is to ballast the entire surface of the mat evenly, so as to nearly destroy the flotation, and then complete the loading from barges, beginning at the head and sinking the entire mat at once.

The breaking up of this mat was undoubtedly due to the method adopting of sinking, as no difficulty was experienced with any of the others; under ordinary circumstances, and where proper precautions are taken, no trouble in sinking these large mats need be anticipated, as instanced by work of this class previously done at Greenville, Bolivar, and the other large mats afterwards constructed here.

On September 10, a month after mat No. 1 had been sunk, while the upper slope was being graded, the bank began slipping out, parting the few holding-in cables and pushing out the mat itself, as shown by willows forced up to the surface by the movement of the mat below.

This sliding of the upper bank continued at intervals, as the grading proceeded, as far down as station 17, necessitating the building of a number of large and expensive mats afterwards to connect the main mat with the shore.

The trouble, it is thought, was caused by the great quantity of water pouring down the slope, thoroughly saturating the lower part, until the material became in a semi-fluid condition, which, being forced against and under the mat, moved it bodily out into the river, as at this particular locality the bottom was soft, formed by a deposit of silt, which when once put in motion carried with it the mat.

In all the other mats the full number of shore cables were put in (every 16 feet) and the precaution taken to pull them up taut with a pair of small blocks, following up close behind the grading.

No more slipping took place.

Grading the slope.—Much more could have been accomplished, and a great deal of expense saved, in the execution of the work, had the grading preceded instead of followed the mat construction.

Among the practical difficulties arising from grading the high banks after the mattresses are in place, may be enumerated the fact that the saturation of the slope by the stream of water running over it, where the material is sand or silt, causes holes and caving and breaking down of the edge near the water-surface.

It is necessary, in order to keep up with the mat-building, to fill these holes with earth and lay the stone on without sufficient time for settlement, whereas, had the grading been done first, the grade would be in much better condition to receive the stone covering, having had more time to settle.

The cables which hold the mat into the shore are led over the top of a nearly vertical bank and fastened before the mat is sunk. In bringing the upper bank to the proper slope the scare loosened, and give no assistance to prevent the sliding out of the mat at a time when it is subjected to an enormous strain from the slipping down against its edge of the material washed from the bank in a semi-fluid condition.

Inasmuch as the low-water season is of short duration, and it is only at the lowest stages that the upper bank grading can be carried on, the amount of revetment work that can be finished in any one season depends upon the length of bank that can be graded before the river rises.

And as the grading is necessarily the length of one mat from 800 to 1,000 feet behifd (by reason of the space occupied by the head and mooring lines to the lower mat under construction), it is compulsory to stop mat-building before the river rises to any extent, in order to have sufficient time to grade and revet the slope in front of the mat, or else leave this work in an unfinished condition with the lower part of the slope ungraded.

Among the advantages of grading ahead of the mat construction are—

First. The graded bank allows the holding-in cables to be permanently fastened before the mat is sunk in place, thus preventing any slipping or sliding out of the mat from the shore.

Second. The whole of the low-water season can be utilized for work in mat-building; the mat construction can be carried up the graded slope as the river rises, thus allowing more work to be accomplished.

Third. It is a great saving of expense, as the graded slope affords ample space to unload rock from barges at the place it is to be afterwards used, and thus saves the expense of rehandling.

The revetment work was finished on December 31, and from the last examination made before the rise in the river covered it with water, was in good condition, except a small part of the extreme lower end of the upper bank, which had slid in, due to caving below the end of the work. Plate 1 shows location of mats as constructed.

The following amount of work was done:

Mattress	squares..	21,694.7
Slope paving	do....	5,671.8
Grading	linear feet..	5,877.0
Material used:		
Stone	cubic yards..	48,160.82
Brush	cords..	18,813.30
Poles	do....	3,362.15
Wire	pounds..	167,440.00
Wire cables	do....	329,560.00
Spikes	do....	36,961.00

The fleet was towed from Wilson's Point, La., to Ashton, La., during June, and on the completion of the Louisiana Bend improvement, December 31, was moved to Greenville.

All the plant, including the old drydock, was brought up without accident. The last tow arrived January 23, 1890.

REPAIRS.

A force of mechanics has been employed in making repairs to the plant. The most important done was remodeling the pits of the two dump-scows built for use in Vicksburg Harbor.

The repairs to the steamer *Meter*, which consisted of new cylinder timbers, new guards and outriggers, a square head put on to adapt her better for towing purposes, new rudders, and extensive repairs to her hull.

The docking and repairs to hull of the headquarters boat, and the rebuilding of two small barges, besides new decks and deck frames put in three of the rock-barges.

Material expended, June 1 to April 30, inclusive.

Stone	cubic yards..	48,160.82	Gas-pipe	feet..	100
Brush	cords..	18,813.30	Limestone	barrels..	15
Poles	do....	3,362.15	Lime	do....	3
Lumber	B. M..	179,994	Asphaltum	do....	6
Coal	bushels..	92,407	Salt	do....	5
Wire cable	pounds..	329,560	Charcoal	do....	5
Wire	do....	167,440	Oil (head-light)	gallons..	1,945
Spikes	do....	36,961	Linseed oil	do....	855
Iron	do....	36,185	Oil (signal)	do....	815
Lead (white and red)	do....	5,785	Oil (lard)	do....	385
Oakum	do....	6,138	Oil (valvoline)	do....	162
Staples	do....	800	Oil (black)	do....	171
Clevises	do....	300	Turpentine	do....	50
Copper	do....	5	Asphaltum	do....	476
Files	No..	135			

Summary of cost of labor, June 1, 1889, to April 30 1890, inclusive.

Classification.	Pay-roll.	Subsistence.	Total.
Care of fleet	$15,631.93	$2,788.41	$18,420.34
Surveys and examinations	2,408.67	512.92	2,921.59
Surveys Lake Providence Reach	1,220.00	140.73	1,360.73
Observations Wilson's Point	1,992.67	415.31	2,407.98
Observations Arkansas City	786.24	185.00	971.24
Protection of levees	43,118.02	4,003.97	47,121.99
Vicksburg Harbor	3,098.28	550.90	3,649.18
Repairs to plant	16,023.51	2,894.15	18,917.66
Louisiana Bend (construction)	57,899.28	13,779.88	71,679.16
Greenville Harbor		13.86	13.86
	142,178.60	25,285.13	167,463.73

Tri-monthly soundings on Lake Providence Reach.

Date.	Lake Providence gauge.	Crossings.					
		Duncansby.	Wilderness.	Vista.	Stack Island.	Ben Lomond.	Ajax Bar.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
June 7	19.50	35.00	.....	.....	.....	.....	.....
8	20.50	.....	31.0	.....	30	24.0	.....
24	25.50	45.00	31.0	.....	27	29.0	.....
July 10	23.75	43.00	25.0	.....	27	30.0	.....
20	17.75	35.00	21.0	.....	19	19.0	.....
31	18.75	41.00	24.0	.....	24	21.0	.....
Aug. 11	19.00	43.00	19.0	.....	21	19.0	.....
21	14.25	32.00	17.0	.....	22	17.0	.....
31	11.00	12.50	15.0	.....	16	12.0	.....
Sept. 10	7.75	27.00	13.0	.....	13	13.0	.....
20	10.75	28.00	15.0	.....	17	14.0	.....
30	8.5	27.00	14.0	.....	14	12.0	.....
Oct. 11	6.5	23.00	13.0	12.0	12	10.5	.....
21	4.25	18.50	11.0	10.0	12	8.0	.....
31	3.00	17.00	12.0	8.5	11	8.5	.....
Nov. 1	2.25	17.00	12.0	8.5	11	8.5	7.0
11	5.90	20.00	17.0	13.0	13	11.5	10.5
20	16.50	29.00	20.0	23.0	20	20.0	21.0
30	23.00	40.00	28.0	35.0	26	25.0	28.0
Dec. 10	24.25	37.00	28.5	33.0	30	26.0	30.0
20	15.75	31.00	21.0	21.0	20	17.0	20.0
30	17.00	35.00	21.0	26.0	24	16.0	22.0
Jan. 11	23.00	41.00	24.0	29.0	33	18.5	24.0
20	30.25	50.00	32.0	39.0	42	26.0	33.0

Soundings were discontinued after January 20 on account of the high stage of the river.

FINANCIAL STATEMENT.

Lake Providence Reach.

Balance May 31, 1889		$467,046.33
Transferred to protection of levee, third district	$55,000.00	
Transferred to protection of levee, fourth district	45,000.00	
Expended to June 30, 1890	360,519.67	
		460,519.67
Balance June 30, 1890 (in hand)		6,526.66
Expenditures apportioned as follows:		
Labor on construction		51,632.62
Material for construction		199,431.48
Subsistence		27,557.46
Cost of plant, repairs, and outfit		40,229.37
Care of public property		19,229.90
Towage and steamer expenses		11,345.29
Administration and office expenses		7,026.94
Surveys		1,941.09
Medicines and medical attendance		1,207.72
Miscellaneous		917.80
		360,519.67
Balance June 30, 1890	6,526.66	
Less liabilities	3,006.56	
Available balance June 30, 1890		3,520.10

There are no existing contracts.

Amount that can be profitably expended in fiscal year ending June 30, 1892 ..... 750,000.00

VICKSBURG HARBOR AND DELTA POINT.

Until the year 1876 the Mississippi River flowed directly in front of the city of Vicksburg. In that year the river made a cut-off across the narrow neck of land forming the opposite bank, thus leaving the city on a lake, and its wharves and business houses distant from the river about 2 miles. The rapid caving of the bank at Delta Point, Louisiana, opposite Vicksburg, after the occurrence of the cut-off threatened to throw the river still farther away from Vicksburg, while the rapid and continuous shoaling of the lake, and especially of the entrances thereto, tended to prevent direct communication with Vicksburg, except during the higher stages of the river. It was thus seen that Delta Point should be held, to prevent further recession of the river from Vicksburg and to maintain the regimen of the river immediately below, and that an improvement of the harbor proper (Centennial Lake, in front of the city) was desirable.

The protection of Delta Point, by revetment, was commenced in 1878, and was carried on in succeeding years until 1884, since which date only repair work has been done. Altogether 10,700 linear feet of bank was revetted. The work has proved entirely successful. It will need repairing, however, from time to time to insure its permanency, and may have to be extended up-stream, should rapid caving there continue. No repairs were made during the past year.

Several plans for the improvement of Vicksburg Harbor proper have been proposed. The one under which work is now being done was approved in 1887, and is as follows: To prevent the flow of water into the lake and make it a still-water basin in front of Vicksburg; then to dredge a basin in front of the town and a canal connecting this with the river.

The original plan, with its modifications and the history of the progress of the work, are given in the Reports of the Chief of Engineers from 1878 to 1889, inclusive.

The principal work done during the past year was the removal by dredging of 357,468 cubic yards of material, principally from the canal connecting the river and basin.

A detailed account of all the year's operations is given in the following report of Assistant Engineer Coppée, who was in local charge of the work:

REPORT OF MR. H. ST. L. COPPÉE, ASSISTANT ENGINEER, ON WORK DONE DURING THE YEAR ENDING MAY 31, 1890.

As stated in last year's report, the double-ladder Menge dredge was purchased from Joseph Menge, of New Orleans, and when that report was submitted she was on trial in the west end of Centennial Lake, Vicksburg Harbor. The dredge at that time did not work very satisfactorily, and owing to a defect in and breaking down of the scows we were unable to give it a fair test. Some slight changes were made in the machinery of the dredge at that time.

Early in June, as the water in the canal was sufficiently deep to operate the dredge, she was placed there, her chute being extended to one side, so as to throw the material well out on the bar; she was thus worked, the little material excavated being thrown to the bar side of the canal.

The reason for operating the dredge in this way was because the scows were unfit for use, until they could be strengthened and repaired, and we had no means of obtaining others with moderate expense.

A log of the work performed was sent to your office until July 10, when it was deemed expedient to close the work, as little good was being accomplished and the material placed on the bar would eventually have to be moved again.

The difficulty experienced with the dredge was the impossibility to keep her in line, the constant slipping of the rubber belts, thus failing to carry requisite power to the dredging parts proper, the rapidity with which the great friction on the crane tracks wore them out, the constant breaking of sprocket teeth, the bad working of the sprocket machinery in front for moving the dredge, and the small percentage of material moved.

The dredge was towed to the north end of Centennial Lake and laid up for the summer, cared for by a responsible watchman.

While running she was in the immediate charge of Mr. Hy. Steubing, who used every effort to work her successfully.

Since last summer, up to February of this year, owing to low water and other unfavorable conditions, no work of dredging was done in the harbor. Early last year a contract was entered into with the Alabama Dredging and Jetty Company, of Mobile, Ala., to dredge a canal and basin in front of the city, in accordance with plans and specifications submitted in former reports, for 10 cents and 12 cents per cubic yard, measured in scows, the latter price being for long haul around De Soto Island to north side of dam.

After the close of work at Greenville, I was ordered by Captain Leach to return to Vicksburgh, with a view to making the necessary repairs on the Menge dredge and placing her in commission, as the water had risen sufficiently at that point to warrant a commencement of excavating in the canal in front of the city. Some slight repairs were made, and the dredge was towed to the mouth of the south end of the canal. The rise proved but a temporary one, and the dredge worked with such poor success that I asked for instructions to be allowed to change the machinery in many respects and make numerous additions to her outfit.

December 21, the dredge was laid up for repairs. I will state here that Mr. Steubing urged the change of the sprocket machinery for moving forward, in the summer, but I had deferred doing so, with the hope that we could work it to better advantage after educating the crew, but this proved unsuccessful.

As soon as I returned here in December, I at once commenced, with the assistance of Mr. Charles Miller, assistant engineer, to establish the base lines of the former survey, to which all harbor-lines were referred. Soundings were made also, in order to obtain the changes that had taken place during the year and determine the material to be moved within the limits of our original cross-sections and within the means of the available appropriation.

After making the survey, I sent to your office the following estimate of material required to dredge the canal and basin to +6, +5, +4, +3, +2, +1, 0, and —5-foot planes on the gauge, showing the yardage as it existed last year and the additions for sloughing and fill during the year:

+6 feet on gauge:		
Canal and basin, 1889	cubic yards..	621,138.04
Add for fill during year	do....	39,405.80
Total for 1890	do....	660,543.84
+5 feet on gauge:		
Canal and basin, 1889	yards..	692,984.42
Add for fill	do....	39,584.83
Total for 1890	do....	732,569.25
+4 feet on gauge:		
Canal and basin, 1889	do....	767,258.23
Add for fill	do....	39,759.69
Total for 1890	do....	807,017.92
+3 feet on gauge:		
Canal and basin, 1889	do....	844,001.02
Add for fill	do....	39,975.13
Total for 1890	do....	883,976.15
+2 feet on gauge:		
Canal and basin, 1889	do....	923,181.96
Add for fill	do....	40,176.20
Total for 1890	do....	963,358.16
+1 foot on gauge:		
Canal and basin, 1889	do....	1,004,817.55
Add for fill	do....	40,374.38
Total for 1890	do....	1,045,191.93
0 on gauge:		
Canal and basin, 1889	do....	1,091,306.14
Add for fill during year	do....	40,550.40
Total for 1890	do....	1,131,856.63
—5 feet on gauge:		
Canal and basin, 1890	do....	1,561,091.55
Add for fill	do....	40,508.64
Total for 1890	do....	1,601,600.61

There was no appreciable fill in the basin, and the fill in the canal took place only in what constitutes the present channel at the lower end (below range 52) where it was found to have extended over the entire bar, although very lightly.

The explanation of this lies in the fact that the river, during the season of 1889, scarcely came up over the surface of the ground west of the present canal, and then only for a short time, while it remained in the canal for quite a long time. Hardly an appreciable fill was detected at range 5, which was taken as 0, or the starting point. At range 15, the fill averaged about 6 feet, at range 25, it was about 1.2 feet, at range 35, 1 foot, at range 45, 1½ feet, and at range 50, 2.8 feet, at range 55, 3½ feet; below this it was very irregular, even showing a scour at some places, which is due to the fact that this part of the canal comes directly under the influence of the eddy water of the river. Since the date of these observations, the river has attained the highest point recorded since 1862. For over three months, since February 15, the water has been above 45 feet on the gauge, and above the crest of the pile-dam closing Lake Centennial. During this period, a current of considerable force has swept south along the city front, reversing the conditions that existed last year, tending to scour rather than fill in the line of the proposed canal and basin. The water has been too high, and remains too high at the present date, to make accurate observations in order to determine the extent of this change. The velocity of the current in the canal during this high water, has varied from one-fourth foot per second to 2 and 3 feet per second. The loose, soft material composing the surface of the bed of the canal, has been swept away.

At the beginning of the year I was notified that $79,000 was available for dredging in this harbor, $50,000 to be spent by the contractor at 12 cents and 10 cents per yard, measured in scows. For convenience in estimating, I take 11 cents per yard as the average, which is equivalent to 15 cents in place, approximately, when allowance is made for the expansion of material. The contractor could move, at that price, 340,000 cubic yards. Taking from the $29,000 left for working the Government plant, the following:

Survey	$534.00
Repairs to dike	1,050.52
Superintendent and inspectors, etc	700.00
Repairs and working Menge dredge	8,108.63
Purchase of tug *Parker*	6,500.00
Total	16,893.15

leaves a balance of about $12,000, and when office expenses and inspectors and superintendence are deducted from this we have but about $11,000 for dredging with the Menge plant. This estimate is made to May 1, at 6 cents per yard, which is allowing for but 1,000 yards capacity per day, or half that guarantied by contractor; we have, say, 180,000 cubic yards, or 250,000 cubic yards moved by the combined plants. This will take us to the +8-foot plane.

I had anticipated dredging, at first, to the +7-foot plane, but so much expense has been incurred in repairs to the Menge dredge that that plane had to be abandoned. The $11,000 should insure work for four months with the Menge dredge, and remove, as stated, 160,000 cubic yards of material. This, of course, depends on the success in working the Menge dredge which, up to the present time, has proved anything but a successful machine.

February 24, the river being at a sufficient height, the contractor's dredge *Shelly* which had been sent from Mobile, Ala., in compliance with contract, was placed in line of canal, and commenced operations, working two watches, or twenty-four hours per day.

This dredge is a clam-shell digger, with 4-yard bucket, and a capacity of about 3,000 cubic yards in twenty-four hours; she has been working constantly and successfully up to the present time, moving the material from a depth equivalent to +12 feet on the gauge, it being impracticable to dredge to +8 feet in the present high water.

April 2, the *Herndon*, another of the contractor's dredges, commenced work, also in line of canal; the latter is the same dredge that worked here in previous years; a full description of which will be found in former reports; she is also a clam shell, but of greater capacity, being capable of moving 4,000 to 5,000 cubic yards in twenty-four hours. This dredge is working but one watch of about fourteen hours, but is moving as much material per month as the *Shelly* with double crew.

The material moved up to June 1 by these dredges, measured in scows, is as follows:

Herndon	cubic yards	125,593
Shelly	do	224,168
Total	do	349,761

In the same time the following amount has been expended, $20,777.80, leaving a balance of $29,222.20 for the contract work.

Two inspectors on the *Shelly* and one on the *Herndon* are constantly employed by the Government, to keep a correct account of the material moved, and to see that the dredging is kept within the required cross-section; also a man is employed to see that each load on the long haul is dumped exactly along the line of the pile dam, in order to make a continuous earthen dike, as explained in former reports. If the rate of progress continues the same, it is probable that the contractor's work, to the full amount of the allotment of $50,000, will be completed early in July. In event of the passage of the river and harbor bill before that time, it would be greatly beneficial if an arrangement could be made by which the contract could be extended and the dredges kept at work, thus doing away with the necessity for further advertising and delays in making a new contract.

At the beginning of the year, before the water rose, it was proposed to repair the dam across the lake, where it had, owing to the rotting of the timber, broken down. Some piling braces and stringers were obtained for this purpose, also 22,000 feet, B. M., of lumber was purchased, but the river rose so rapidly that only a small part of the repair work was accomplished (115 piles were driven and braced). We have on hand now a few braces and stringers and a large part of the lumber. As the former will be but little loss if not used, and the latter could be used at other points (Greenville) for other purposes, and as the water will probably fall in a short time below the crest of the earth dumped along the dam, I would respectfully suggest that this repair work be abandoned until another year.

The plant in use here at the present time is as follows: One Menge dredge and outfit; two dump-scows, average each 200 yards; one tug, *Parker*; one quarter-boat, one barge, one pile-driver, two calking-flats, four skiffs, and one yawl.

The tug *Parker* was purchased at St. Louis during the first quarter, and has proved a very fine boat.

The contractors' plant consists of the following: One dredge, *Shelly*; one dredge, *Herndon*; four large scows, capacity averaging 475 yards each; two tugs, *Kaiser* and *Mamie*; four small boats.

Before giving the details of the work and repairs on the Menge dredge, it would be well to submit the following description of that machine:

The dredge (of the endless chain or ladder patent) was built by Joseph Menge, of New Orleans, La., in accordance with specifications accepted by Captain Rossell, in 1889, and is now the property of the United States Government. It is 95 feet long, 40-foot beam, 5 feet depth of hold, made of two barges, 15 feet beam each, with a 10-foot space between, forming a well for two bucket cranes. The two barges are held together transversely by six pieces of pine, 6 by 5 inches, on deck, with angle irons beneath; also, by three 1¼-inch rods near stern, extending across the barges to outside. There are six braces between the barges, 6 by 12 inches by 10 feet long, butting against the outside, these braces having angle irons at each end, secured to sides of barges. Each barge has 8 by 14 inches lower gunwales, 4 by 16 inches tie braces (3 feet center to center) dove-tailed into gunwales, and six fore and aft keelsons 4 by 10 inches on edge, with tie braces pinned to same. The sides and ends are of 6 by 12 inch lumber, bolted with ¾-inch drift-bolts, 18-inch centers. There are 8 by 8 inch corner posts and 6 by 6-inch stanchions in hull, also, 3 by 12 inch bottom plank laid crosswise, fastened with ⅞ by 7 inch spikes. The beams are 4 by 8 inches, laid transversely, with 26-inch centers let into side 1¼ inches and drift-bolted. The deck is 2 by 8 inch plank, fore and aft, secured with 30*d* nails. The middle keelson is 6 by 15 inches, running fore and aft, and pinned to 4 by 6 inch tie braces, with 4 by 4 inch studding between it and the deck-beams. Each barge has a square-built end aft, and rake forward built outside of the main body of the dredge. The hull outside and inside is well painted and saturated with creosote oil. There are two spud wells in dredge—one aft, the other forward of bucket-crane well, which occupies middle of dredge. Each spud well is lined at bottom and top with 4 by 1½ inch steel friction plates; the two spuds are made of four pieces of pine, well bolted together edgewise; the finished spud being lined with 3 by ⅝ inch steel bars, two to each side and one on each edge. The spuds are raised by a rack let into side of spud and pinion connected by gearing to steam-power in case of forward spud; the aft one to worm-gear worked by band. The lower end of each spud has a curved cast-iron cutter let into and secured to it to direct the motion of the dredge while working. Four pairs of 8 by 10 inch and two pairs of 8 by 10 inch uprights at the stern of the dredge, capped, braced, and securely fastened with bolts, receive the working parts of the dredging machinery and support the upper ends of the cranes, the hopper, and the delivery troughs. The latter are so arranged that the excavation can be delivered to right or left of dredge, or on both sides at once. This stern-frame is guyed or braced by fore and aft 1½-inch hog-chains. A hinged chute extends from each side of frame-work, supported by derricks and hangers. A little forward of midships, a frame composed of two 10 by 10 inch uprights, with 10 by 12 inch cap pieces, two pair of 4 by 10 inch side braces, and two 8 by 8 inch aft braces, all securely bolted,

receive the crane-hoist shives. Also a saw-buck frame is situated midships, with the braces as far down as the oscillation of the crane will allow. Two cranes, 75 feet long each, made of 4½ by 16 inch lumber, extend from stern frame-work through well, being fastened near lower end by heavy chains to hoisting frame. The frames have pine side guides 2 by 10 inch; tie braces 4 by 10 inches, and floor 2½ inches thick. Each crane oscillates from a point clear of the water-line to about 30 feet below the surface. At the stern of the dredge is located the cabins, kitchen, tool and store rooms, and all accommodations for crew and their subsistence. For working the dredge, moving the buckets, changing the position of inclination of the cranes, and moving the dredge forward, the following machinery is used on each barge, it being possible to work one or both cranes, as may be desired, and therefore one or both sets of machinery. Each barge has just aft of midships and in front of cabins, an Atlas engine 11 by 15 inches with reversing gear, and a 40 horse-power Atlas boiler complete, a duplex Worthington steam-pump with connections to bilge, to boiler, and to hose, with 2-inch suction and 1½-inch discharge. These large engines run a 4-ply 12-inch rubber belt connected with pulley, running shaft to which is geared a sprocket wheel, which sets in motion the endless-chain carrying buckets. There are two sprocket wheels each containing twenty eight sprocket teeth (on each side). There are four 42-inch idler wheels, regulating the position or sag of the buckets in the reversed condition. One steel shaft and one cutter wheel is fastened at lower end of each crane to cut up the material before it comes in contact with the bucket. There are thirty-five dredge-buckets on each pair of chains (approximate capacity of bucket, 3½ cubic feet). The buckets have bottom shell of ½-inch iron, top shell ½-inch steel, cutters 3½ by ½ inch steel, cross-bars 1½-inch round iron. There are two tracks, 3 by ⅝ inch iron, on top of each crane incline, and two side-tracks, 2 by ½ inch iron. The top tracks were originally steel, but wearing out in a short time were replaced by wrought-iron. One 8 horse-power donkey-engine is used on each side in hoisting-cranes by means of worm gear and heavy chain-drum. The chain (1½-inch proof) working through heavy shieves in forward frame and fastened to crane by two 3 by ½ inch iron hangers (hanger-rods 2½-inch). The donkey-engines are also used in moving the dredge forward by sprocket chain-gear and spools on shafts, and also hoists the forward spud. The endless chains working over crane-track and idlers and through sprocket teeth, carrying buckets, two to each crane, are of 2 by ½ inch Bessemer steel loops and links of round refined iron alternating, the link being square. A deck-pump is situated in front of laborers' quarters and just back of right-hand boiler, being used for pumping up boilers, cleaning, etc.

In order to dredge, the cranes are lowered to the required depth, the spuds let into the ground until the iron blades are well under the surface, and the large engines then put in motion. The cutters break up the hard material and the buckets take it up and carry it to top of crane, throwing it into the hopper at upper end. In turning to lower side of crane from the hopper, the material slides by its own weight into the troughs and thence into the dump-scow at side. This description is in part taken from the specifications, which were followed very accurately in building the dredge, and gives the condition before the numerous repairs and changes had been made.

It was not until we found it impossible to obtain good results, or, in fact, to do any work worth mentioning, that it was determined to make radical changes, but after our complete failure in December I recommended the changes, which were made, as follows:

The entire sprocket machinery at bow of boat for moving forward, which had proved very defective, and almost useless, was taken off of each side and replaced by two single-barrel steam capstans. The stern-spud was connected to small reversing engine. Plates were fastened to endless chains in order to relieve them of wearing by excessive friction. In addition to this, the roof was covered and heavily painted, and the dredge given two coats of paint. The two rubber belts (12 inches), which were entirely inadequate to carry the requisite power to the dredging machinery, were replaced by heavy patent link-leather belts. With these additions, the dredge was put to work and commenced digging March 25.

Her record was as follows:

Mar. 25.	Cubic yards measured in scows	100
26.	Cubic yards measured in scows	158
27.	Cubic yards measured in scows	90
28.	Cubic yards measured in scows	200
29.	Cubic yards measured in scows	109
Apr. 1.	Cubic yards measured in scows	200
3.	Cubic yards measured in scows	107
4.	Cubic yards measured in scows	165
5.	Cubic yards measured in scows	250
	Total cubic yards measured in scows	1,514

It was found during this time that the dredge was still imperfect in many respects, and she was laid up once more for changes and repairs. The beam carrying crane-

hangers has been increased in strength (four times). The entire hopper was remodeled and lowered to avoid losing a large percentage of material, as had been the case before. The bearings of main shaft, which were light and unreliable, were strengthened. The iron hangers were increased in size and section. A track and rollers have been placed on cranes, and runners rivetted to buckets to reduce the friction on endless chains and work of engines. This latter is an invention of Capt. Dan Kingman's, of the Engineer Corps, and is in use on his dredge at the mouth of Red River. A double-barrel steam capstan was placed at stern of dredge, to be used in hauling back in cut and regulating position by breast lines. Other small additions were made, and the dredge is now ready for work. It is hoped, with these changes, she will be able to move at least half the material for which she was designed. It will be impossible, as she has just commenced work, to make any extended record or estimate of her performance to accompany this report. Her record for the few days she has been operated is as follows:

May 14.	Cubic yards measured in scows	601
15.	Cubic yards measured in scows	287
16.	Cubic yards measured in scows	540
17.	Cubic yards measured in scows	305
19.	Cubic yards measured in scows	325
20.	Cubic yards measured in scows	427
21.	Cubic yards measured in scows	390
22.	Cubic yards measured in scows	151
	(Broke gear-wheel.)	
26.	Cubic yards measured in scows	652
27.	Cubic yards measured in scows	701
28.	Cubic yards measured in scows	320
29.	Cubic yards measured in scows	742
30.	Cubic yards measured in scows	182
31.	Cubic yards measured in scows	572
	Total cubic yards measured in scows	6,193

The original plan and history of the beginning and progress of the work on this harbor is given in former reports, dating from 1878 to the present time.

In regard to Delta Point, it will be impossible to make any report or estimate for repairs or new work.

Before the high water, early in the winter, the revetment was in comparatively good shape.

There was some caving in the reach above where Captain Russell recommended a large expenditure. What the high water has effected at that point, it will be impossible to state until the river reaches a much lower stage.

During the flood, which is just subsiding, we were called on a number of times to assist in protecting levees. I made a trip to the Raleigh Crevasse, at the request of the president of the fifth district, Louisiana Levee Board, and with the assistance of Mr. C. J. Coney, succeeded, in a very short time, with the aid of plant and laborers furnished by levee board, in stopping the caving at ends of break, by means of mattresses built of willow facines and rope, and sunk with sods of earth. This method, I believe, can be made successful where every other means fails. The tug *Parker* was used by the levee board for over two weeks, and we have endeavored to assist in every possible way, as you directed, in saving the levees and property endangered by the flood.

FINANCIAL STATEMENT.

Vicksburg Harbor.

Balance May 31, 1889		$108,205.73
Expended to June 30, 1890:		
Cost of plant, outfit, and repairs	$21,410.35	
Labor, repairs to dam and dike	450.17	
Material, repairs to dam and dike	904.98	
Subsistence	1,278.92	
Care of public property	559.18	
Dredging by United States plant	7,202.08	
Administration, inspection, and office expenses	3,215.79	
Dredging under contract	35,267.55	
Surveys	534.00	
Miscellaneous	76.96	
		70,899.98
Balance June 30, 1890		*37,305.75

* Fifteen thousand dollars of this amount reserved for repairs to Delta Point.

Of which:		
In treasury	$15,000.00	
On hand	22,305.75	
		$37,305.75
Less liabilities	4,806.17	
Less amount covered by existing contracts	11,296.06	
		16,102.23
Available balance June 30, 1890		*21,203.52
Amount that can be profitably expended in fiscal year ending June 30, 1892		175,000.00

Delta Point, Louisiana.

Balance May 31, 1889	$156.58
Balance in hand June 30, 1890	156.58
Available balance June 30, 1890	156.58
Amount that can be profitably expended in fiscal year ending June 30, 1892	150,000.00

GREENVILLE HARBOR.

The city of Greenville is situated in a deep, concave bend of the river, and is built entirely upon alluvial land. Rapid caving of the bank had been going on for some years, until a considerable portion of the business part of the town had been destroyed.

In the river and harbor act, approved August 5, 1886, a special allotment of $37,500 was made for preventing the bank at Greenville from further caving. The Mississippi River Commission decided, after an examination of the locality had been made, not to begin work here under this allotment, as the amount available was considered too small to warrant the inauguration of operations.

The city of Greenville subsequently placed $42,277.10 in the hands of the Commission for bank protection work. A project was thereupon prepared by the officer in charge of the district, which was duly approved by the Commission and carried out by the district officer, and which contemplated the building of ten sloping spurs along the city front, at intervals apart of about 500 feet, and similar in construction to those previously built at New Orleans and Memphis.

The results of the work were generally satisfactory, as pointed out on pages 2706, 2707, Annual Report of Chief of Engineers, 1889. The overfall over the dikes, however, produced a scouring effect between the dikes near the shore, which caused a slipping and caving of the bank between the dikes. The funds being practically exhausted, nothing could be done to prevent this until a further allotment should be made.

The river and harbor act, approved August 11, 1888, appropriated $75,000 for continuing work, in accordance with the plans and specifications of the Mississippi River Commission at Greenville, Miss. With the funds thus provided work was resumed, and during the year ending May 31, 1889, four mattresses were built and sunk along the bank between the dikes to prevent further caving there, and 706 feet of the bank along the foot of the island, immediately above Greenville, were revetted, as the rapid caving at this point threatened the improvement below.

A detailed report on the Greenville dikes by Assistant Engineer Hider is hereto appended.

The work done during the year ending May 31, 1889, is set forth in detail in the following report of Mr. H. St. L. Coppée, assistant engineer, who was in local charge of the work.

The high stage of the river has prevented the making of an examination of the work, so that its present condition and the improvement resulting from the work are unknown. The bank for several miles above Greenville is caving rapidly, and should be revetted, both for the general improvement of the river and for the protection of Greenville and its harbor.

* Fifteen thousand dollars of this amount reserved for repairs to Delta Point.

REPORT OF MR. H. ST. L. COPPÉE, ASSISTANT ENGINEER, ON THE WORK DONE DURING THE YEAR ENDING MAY 31, 1890.

On being relieved of the Ashton work I was ordered to Greenville, to take charge of the repairs and new work contemplated at that point. The plant used for this work was: Two quarter-boats, one calking-flat, one pile-driver (used as bank grader with trough), two model barges, six square barges, two yawls, two skiffs, one steamboat, *Vidalia*.

For years the river-front of Greenville had been caving away, necessitating periodical moving back of the houses, and in fact of the entire town, to avoid being swallowed up by the ravenous water of the Mississippi River. The old town, established just after the war, and before the bank caving commenced, was situated over a mile west of the present site. The intervening land is now occupied by the bed of the Mississippi River, and at low water the Arkansas bank extends far over what was formerly the old Mississippi territory.

In order to regulate this part of the river, as well as protect the city front, the Mississippi River Commission commenced work in the fall of 1887; the plan being to stop the erosion of the bank by means of submerged spurs or sills, located 500 feet apart, resting on mattresses and extending beyond the deepest water or the channel line immediately next to the shore.

Ten dikes similar to that shown in Plate No. 1 were constructed in the fall and winter of that year, under the local direction of Mr. Arthur Hider, and they have proven very successful in checking the caving, and restoring a permanent front to the city of Greenville. (For detailed reports and maps of the work of 1887, see Report of Chief of Engineers, 1888, Part IV, page 2280.)

After the completion of the work of 1887, or during the low-water of 1888, a survey demonstrated the fact that extensive caving had taken place in the bend above the immediate city front and along the island that threatened the system of dikes.

A mattress 706 feet by 250 feet was built and sunk in position, and the upper bank revetment completed just above the island, in the winter of 1888. (See Report of the Chief of Engineers, 1880, page 2707.

This latter mat and revetment was badly broken up, and the face of the island was caving when work was ordered to be done in August, 1889. Captain Rossell at first contemplated building three submerged (crib) spur-dikes in the positions marked A, B, and C on the map, but owing to scarcity of funds and change of plans, the point A was protected by a pile-dike 200 feet above the upper or last dike of the system built in 1887. The other dikes A and B were built 500 feet apart, the latter being located on the mattress sunk in the winter of 1888–'89.

The work under my charge was simply the extension up the river of the original system of dikes, to stop the caving that had occurred recently above the other protection works.

More in detail, the work consists of cribs forming two dikes built of willows, wire, and stone, constructed at an interval of 500 feet in length of bank, and reaching out beyond the deepest water in the channel of the river next the shore. The purpose they are expected to serve, as stated before, is the protection of the bank immediately at the point they occupy, and the indirect protection of the intermediate spaces by deposit, due to the eddy and dead water formed by their position out in the swift current of the river. Each dike was constructed as follows: The sites of the proposed mattresses and cribs having been selected, and soundings having been made, to define the profile of the bank and the distance to the channel, or, in other words, an accurate hydrographical survey having been made of the locality, a mattress was built at B, 290 feet long by 290 feet wide, extending about 50 feet beyond the channel line. At C one was built 250 feet long by 275 feet wide. The mattresses were constructed on floating ways of willow, brush, and poles, wire and spikes, and as woven launched off into the river; when finished and all afloat, and all necessary lines and cables fastened to the shore, they were sunk into place on the submerged bank, with rock wheeled and thrown from barges. The mattress acts as the foundation of the cribs which form the dike. The dimensions and general form of cribs is governed by the profile of the bank immediately at the points where it is proposed to build the dike. At B and C, Plate 1, cribs were built of uniform section; in each case the dike being composed of two cribs. In Dike No. 1, or C, the lower crib was 240 feet long, 32 feet wide, and 8 feet high the upper one 190 feet long, 16 feet wide, and 6 feet high. At Dike No. 2 (B), the lower crib was 212 feet long, 32 feet wide, and 8 feet high; the upper one 170 feet long, 16 feet wide, and 8 feet high. The center of Dike No. 1 averages 90 feet below the up-stream edge of foundation mattress, and center of Dike No. 2, 90 feet below up-stream edge of its mattress.

The dikes are finished with a uniform surface as nearly as possible, and a slope of from 4 to 1, to 5 to 1, from river end to top of graded bank. As a rule, in this work the crib is a right rectangular prism, the top one having a base of 16 feet and depth of 8 feet, with variable length depending on conditions existing in bank and

channel lines; the next one below is 32 feet by 8 feet by variable length; the next, 48 feet by 8 feet, and so on, each one below in the series being 16 feet wider than the one immediately above. As a general rule, also, three cribs form the dike, but, as before stated in this work, but two were constructed in each dike. Each crib was constructed as follows: A frame-work of poles and willows laid with 8 feet squares was built of the required length and breadth, on its layers of brush, both longitudinal and transverse, were laid, and again another frame, and so on, until the crib was about 3 feet in depth. These frames and intermediate layers of brush were thoroughly sewed together with No. 12 wire and 9-inch spikes; wire being left projecting far above the last frame to fasten the lower to the upper crib-work. Up to this point the crib was built on floating ways, but was then launched into the river at the place where it was proposed to sink it. It was fastened by lines to mooring barges that held it in place, and also fastened to the shore by shackle lines (2-inch manilla rope) leading well up the river, also holding it in place while sinking.

At the intersection of the frame poles, 8 feet apart, upright posts 9 feet high were securely fastened, and to these, as well as the lower frame, a crib was built, pockets being constructed in each 8-foot square, the shape of an inverted frustrum of a pyramid, by dropping back one pole as each layer was laid above the bottom frame. When finished the crib was from 6 to 8 feet deep, with pockets 8 feet from center to center, each capable of holding, approximately, 3 cubic yards of rock. The whole crib, like the lower frame, was securely fastened throughout with spikes, wire, and cable. The sinking of the crib was as follows: after it was securely fastened to the bank by cables, having been placed over the desired location, and after being checked up well by slip lines to the mooring barges, rock was thrown into the pockets until they were filled. When the weight had much more than overcome the buoyancy of the structure the strain on the lines was very great and the crib in a sinking condition; then the slip lines were rendered slowly, care being taken to keep the strain uniform till the crib settled in its place on the mattress. In the case of the second or top crib, it was built 16 feet narrower as above stated, and sunk in the same manner, but on top of the first one, thus forming a sill 16 feet high. After the construction of the mattress the portion of the bank (at the site of the dike) above the water line was graded to a slope of 4 to 1, preparatory to covering it with a revetment of willow and stone, which was connected with the submerged mat.

The grading was done with shovels, the material being thrown into troughs laid on the required slope (as a guide), through which a constant stream of water was forced from a pump on a floating pile-driver; thus each shovelful taken from the face of the crib was cast but once, and carried by the force of the water into the river. The cost of moving the earth in this manner was from 6 to 8 cents per cubic yard, depending upon the consistency of the material forming the bank, which ranged from loose, sandy loam to the toughest kind of blue clay and buck-shot.

After completing the grading the revetment was laid; first, a frame-work of poles in 8-foot squares; then two diagonal layers of brush placed on the frame; then a corresponding frame-work to that below placed on top, and the entire mass fastened together securely with wire and spikes; on this stone was placed so close as to hide the top layer of brush. When the revetment was finished and mattress and cribs sunk, the upper end of the partly submerged crib-work was joined to the top of the bank, the work being accomplished on the ground, the construction otherwise being the same, and the pockets filled with rock as in the case of the submerged work. Great trouble was experienced during the progress of this work in obtaining sufficient reliable labor.

The accompanying abstract and estimate of labor and material gives the details of dimensions, composition, and cost of this work. The great variation in the amount of material and labor expended is due to the (before mentioned) irregular and unreliable labor, the different conditions in stage of river, etc., and slight changes in details of construction. About September 15 considerable difficulty in construction was caused by the rising river and large quantities of floating drift; but, though the work was considerably retarded and the cost increased, no actual loss was sustained.

For this work brush was obtained from Elisha Evins, at 1.27½ per cord; poles from the same party, at $1.47½ per cord; and stone from Gottlieb Hartweg, at $1.5[illegible] per ton. October 30 the work on these two dikes was practically completed, and as there were certain repairs ordered by the Commission at Bolivar, Miss., which it was necessary to make at low water, I was instructed to move the plant to that point and do the necessary work there before the winter rise should take place.

The amount of money spent up to that time was $24,037.76 for the two dikes, or say $12,000 apiece. This is considerably in excess of what it would be under more favorable circumstances.

November the 26th, the repair work at Bolivar being completed, the plant was again moved to Greenville.

At first it was proposed to build at A (see map) a crib-dike similar to those constructed during September and October, but owing to scarcity of funds, and also to

the fact that Captain Leach, who was then in charge of the third district, thought a pile-dike, which would be much less expensive, would answer the same purpose, and as well carry out the plans of the Commission, he ordered such a structure to be erected. The material for this work was in great part brought from Bolivar, and part obtained by Government labor. The dike, as shown on map, was constructed by first sinking in the pocket a mattress 270 feet long by 100 feet wide, and through it driving, as shown, two rows of cottonwood piling, the piles in each row being about 8 feet apart and the rows 20 feet apart; the piles being all connected by double, horizontal bracing, one system near top of piling and the other about 10 feet below. The inner or land row of piling was closely wattled with willow brush, and the ends of the dike fastened well into the bank. This completed the season's work at Greenville, and leaves an unprotected space of river front from the pile-dike to Dike No. 2 along face of island of about 1,500 feet, which by all means should be protected as soon as funds are available for that work; also above Dike No. 1 the bank should be protected for a long distance to stop the caving, which would ultimately endanger the work below. For exact cost and plan of operations see Mr. Hider's report to General Comstock, president of the Commission, made March 30, 1890. He recommends as follows:

Three more dikes to complete system	$30,000
5,000 linear feet of revetment, at $43	215,000
	245,000

The work was practically finished December 16, 1889, and the property left in charge of Mr. C. J. Coney, foreman, until such time as the balance of the fleet should be moved to Greenville.

REPORT OF ASSISTANT ENGINEER ARTHUR HIDER ON THE GREENVILLE DIKES.

LOUISIANA BEND, LA., *November* 30, 1889.

SIR: In compliance with instructions contained in your letter to Capt. Wm. T. Rossell, October 11, which he referred to me on October 16, directing a "report of the general conclusions to be drawn from the Greenville dikes as to their permanence, their effect, their success, and final cost, the following is respectfully submitted:

The data upon which this report is based is derived from comparison of surveys of the locality showing the condition of the dikes from time to time, and from examination at irregular intervals of such parts of the work as were exposed above water.

For a number of years the caving in front of the town has been very rapid. A survey was made in August, 1884, with the view of improving the front, but no work was done at that time. The next survey was that of August, 1887, which was made with the object of properly locating the spur-dikes that were ordered built by the Commission. During this interval of three years the rapid caving of the front had continued, one whole street (Mulberry street, parallel with the river), that contained the principal business houses, had caved away.

	Feet.
At Percy avenue the bank had caved back	400
At Central avenue the bank had caved back	390
At Main street the bank had caved back	640
At Washington avenue the bank had caved back	480
At Davis street the bank had caved back	510

An average distance of 464 feet, and an average yearly rate of 154 feet.

The survey of August, 1887, showed that the location of the dikes would give the best results by placing them about equidistant along the front of the business part of the town. The dikes were therefore located, beginning at Range 4½, at intervals of 500 feet, except the two lowest ones, Dike 12½ and 13½; these were spaced somewhat farther apart, so as to protect the bank at the lowest point, where caving had taken place the previous season.

These dikes had for foundations substantial willow mattresses, extending 200 feet along the bank and out into the river, beyond the zero line from 280 to 420 feet. The dikes were built of willow brush and of cottonwood and willow poles; the top cribs were 16 feet wide, except Dike 4½, which consisted of a single crib 24 feet wide, the cribs increasing in width to 32 and 48 feet at the bottom, where the dike consisted of two or three tiers of cribs, as the case might be. The foundation mattresses in all cases extended out in the river beyond the deepest water; the brush, revetment and the crib-work was continued up to the top of the bank, and this revetment afterwards covered with stone. In lowering the upper cribs to their place great care was taken to have them rest on those below.

The cribs were from 6 to 8 feet deep, and the dikes themselves, when finished, varied

from 6 to 24 feet in height, depending on the number of cribs used. The dikes had an approximately uniform slope from their outer ends to the top of the bank. Ten of these dikes were built, covering about 5,000 linear feet of bank, the work beginning September 16, 1887, and ending January 20, 1888. While the work was in progress, caving took place at Range 10½ and Range 11, but as soon as the foundation mats were in place it ceased at both these points.

On December 29, more than a month after Dike 8½ was finished, a cave occurred just above it, undermining the revetment on the upper slope; an extra mat was built in front of this, and no further caving took place. These slips were undoubtedly due to previous undermining of the bank, as indicated on top of the bank by cracks while the work was in progress. The work stood the ensuing high water and the subsequent fall until late in July, 1889, without showing any break or cave, when sloughing of the bank between the dikes began, and continued during the low-water season from August to November.

A survey was made October, 1888, to determine what the effect of the dikes on the front had been; this survey showed that in every case, except at the extreme ends of the system, there had been eddy action immediately below the spurs, and that the first effect of the dikes had been to induce a scour between them next the shore, and thus cause a slip or cave in the bank between the spurs. This slipping of the bank was from Ranges 6½ to 7½, 7½ to 8½, 8½ to 9½, 9½ to 10½, 10½ to 11½, and just below Dike 14.

At the same time, at Dikes 4½, 5½, and 6½, there was a considerable deposit. This deposit extended up the slope to within 10 or 15 feet of the top of bank, entirely covering the revetment and cribs in places; at Dike 10½ there was also a deposit from 3 to 4 feet deep on the lower half of the revetment. At the other dikes there was no deposit. There was a slight breaking down of the lower end of the upper revetment at dikes 8½, 10½, and 13½, due to undermining of the bank.

The above was the condition of the work when repairs began December 11, 1888. These repairs consisted of three mattresses 185 feet wide, built where the greatest caving had occurred, viz, between Dikes 8½, 9½, 9½ to 10½, 12½ and 13½; a small mat was put in below Range 13½. The mats lapped those already built, with upper-bank protection, extending as high as could well be done without an excessive amount of grading. The repairs were finished January 31, 1888. At the present writing the work is in good condition; the repairs made seem to have accomplished the object for which they were intended, as no further caving has taken place and the work is intact.

Comparing the survey of August, 1887, made just before the dikes were constructed, with that made in October, 1888, shows that there was a scour between the dikes, as indicated by the changes in position of the 30-feet contour nearest the Mississippi shore, which moved in towards the shore.

Between Dikes 4½ and 5½, on Range 5, the contour moved out 60 feet.
Between Dikes 5½ and 6½, on Range 6, the contour moved in 150 feet.
Between Dikes 6½ and 7½, on Range 7, the contour moved in 30 feet.
Between Dikes 7½ and 8½, on Range 8, the contour moved in 30 feet.
Between Dikes 8½ and 9½, on Range 9, the contour moved in 25 feet.
Between Dikes 9½ and 10½, on Range 10, the contour moved in 30 feet.
Between Dikes 10½ and 11½, on Range 11, the contour moved in 40 feet.
Between Dikes 11½ and 12½, on Range 12, the contour moved in 170 feet.
Between Dikes 12½ and 13½, on Range 13, the contour moved out 80 feet.
Below Dike 13½, Range 14, the contour moved out 90 feet.

Again, comparing the survey of October, 1888, with that of January, 1889, shows that the 30-foot contour moved out again in the mean time between seven of the ten dikes, as the effect of the second high water, as follows:

Between Dikes 4½ and 5½, on Range 5, the contour moved out 60 feet.
Between Dikes 5½ and 6½, on Range 6, the contour moved in 20 feet.
Between Dikes 6½ and 7½, on Range 7, the contour moved out 10 feet.
Between Dikes 7½ and 8½, on Range 8, the contour moved out 60 feet.
Between Dikes 8½ and 9½, on Range 9, the contour moved in 80 feet.
Between Dikes 9½ and 10½, on Range 10, the contour moved out.
Between Dikes 10½ and 11½, on Range 11, the contour moved out 55 feet.
Between Dikes 11½ and 12½, on Range 12, the contour moved out 40 feet.
Between Dikes 12½ and 13½, on Range 13, the contour moved in 15 feet.
Below Dike 13½, on Range 14, the contour moved out 40 feet.

In this connection attention is called to the fact that after the dikes had successfully withstood the effects of the first high water the filling up of the pockets between the dikes with sediment took place, not only where the extra mats were sunk to prevent further caving, but below the other dikes also, between which no mats had been placed. This would seem to indicate that, although the first effect of the spurs was to induce a scour immediately below them, the resistance that they exerted to the eroding action of the current caused the maximum effect of the current impinging against the bank to exert itself gradually further out, thus inducing a fill or deposit

immediately below each dike which had at first scoured out, a shifting of the deep-water line farther away from the protected bank, and a corresponding movement of the channel towards the opposite shore.

Comparing the survey of August, 1887, with that of October–November, 1889, shows that the above is the case.

	Feet.
The west 30 feet contour, opposite—	
Range 5, moved in	20
Range 6, moved in	35
Range 7, moved out	20
Range 8, moved out	135
Range 9, moved out	280

	Feet.
The west 30 feet contour, opposite—	
Range 10, moved out	245
Range 11, moved out	165
Range 12, moved out	195
Range 13, moved out	295
Range 14, moved out	230

	Feet.
While the line of deepest water, opposite—	
Range 5, moved out	485
Range 6, moved out	50
Range 7, moved out	65
Range 8, moved in	35
Range 9, moved in.	

	Feet.
While the line of deepest water, opposite—	
Range 10, moved in	90
Range 11, moved in.	
Range 12, moved out	115
Range 13, moved out.	
Range 14, moved out.	50

An examination of the soundings taken in January, May, and October, 1889, shows a general settlement of all the cribs, and at the same time a fill over the foundation mat immediately below. The October soundings show an after fill over Dikes 7½ and 8½. Part of this settlement is undoubtedly due to compression of the willow brush and poles, of which the cribs were constructed, and the rest to scour. The survey of October, 1889, shows that all the cribs are in place.

The maximum height above the foundation mat to the top of the cribs was found from 80 to 120 feet beyond the zero line, and at a point from 225 to 250 feet beyond the zero line; the height of the cribs above the bottom decreased to zero. The average height of the ten cribs above the foundation mats at the deepest points was 15 feet. The profiles indicate a scour at these points below the general level of the bottom. As this may be considered the foot of the upper bank slope, it is important, to insure stability to the work, that no scour should take place here. The advisability of lower cribs at this point gradually decreasing in height to the level of the foundation mat 150 feet farther out, suggests itself from a careful examination of the profiles as likely to give better results than cribs of greater height, for the reason that both the overpour and eddy action would be less.

As to the permanence of the improvement; from a careful examination of the locality and its present condition, I see no reason why the dikes may not be considered as permanent as could be expected of this class of work, provided that the system is extended up-stream, or other improvements made which will prevent the dikes being destroyed, from cutting back and working down of the bend below. The effect of the dikes has undoubtedly been to hold the river front, and to gradually shift the deep water away from the protected shore. The success of the work has given a new impetus to business in the town, and the money spent by the citizens on the improvement has already been returned to them in increased value of property. New business enterprises have sprung up, and a general feeling of confidence in the stability of the improvement prevails.

Final cost.—The original cost of the ten dikes was about $10,000 for each dike. To extend the system to connect with the two dikes finished this season, three additional dikes should be built, and above this 5,000 linear feet of revetment will be required to protect the caving bend, so as to render the improvement complete and permanent. These mattresses should extend out 300 feet beyond low water. A modified plan for this work, combining the continuous revetment and low spurs, is submitted herewith, and an approximate estimate of cost. The estimated final cost of completing the improvement of Greenville Harbor on the plan proposed, is as follows:

Cost of ten dikes built in 1887	$101,011.03
Repairs to same and mattresses at head of Island 93, 1888	39,565.78
Cost of two dikes built in 1889, about	24,000.00
Cost of three more dikes to complete system	30,000.00
5,000 linear feet of revetment on the proposed plan, at $43	215,000.00
Total estimated final cost	409,576.81

PROPOSED PLAN FOR BANK REVETMENT.

The following modification of the plan heretofore followed in protecting caving banks, or, more properly, a combination of the continuous mattress revetment and

spur-dike system, suggests itself from an examination of the effects of the Greenville dikes, and from experience in executing both of these classes of work at other localities.

The main advantages are—

First. Extra strength at the foot of the upper slope, where the undermining of the bank begins.

Second. Utilizing the overlapping of the main mattresses as a foundation for the dikes.

Third. Constructing the dikes as part of the main mattress, and with such profiles as from a study of Greenville dikes promise the best results.

Fourth. Saving of stone on the extreme upper part of the slope.

Fifth. Thoroughness of work and method of procedure, allowing the greatest amount of work to be done during low water.

DESCRIPTION OF THE PROPOSED PLAN.

First. To grade the upper bank to a slope of 1 on 3½ or 4 before any mat building is done.

Second. To build a shore-mat reaching up the slope to about 15 feet stage, and extending out in the river to, say, 50 feet beyond the low water-line. Should the stage of water, after the bank has been graded, be too low to allow this to be done, a revetment of brush to be carried up to the proper height as part of the shore-mat. This shore-mat, or shore-mat and brush revetment, to be 100 feet wide, and to be finished before the building of the main mattress begins.

Third. After the shore-mat is in place, to construct the main mattress, extending 300 feet out from the low water line, the inner edge resting on the shore-mat already in position. This main mat to be built in sections of 550 feet, and to be secured by ¾-inch cables to fastenings on top of the bank, the upper and lower 50 feet to be cribbed up with poles, so as to form the foundation of the dikes, each mat to overlap the upper one 50 feet. In the middle of this foundation a low dike is to be built 16 feet wide, 6 feet high, at a point 100 feet beyond the zero line, and decreasing in height both ways from this central point to zero at the inner edge of the mat, and at a point 250 feet further out. This dike to form a part of the head of each mat, as shown on plan.

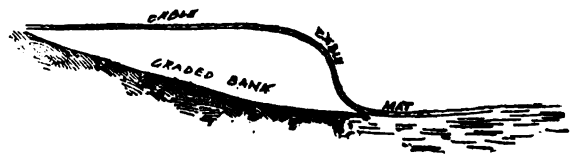
Fourth. From low-water line to within 5 feet measured vertically from the top of the bank, the upper slope to be covered with stone 10 inches thick.

The following are some of the advantages of the method proposed:

The grading of the upper bank before any mat building is done suggests itself from practical difficulties that arise in grading the high banks after the mattresses are in place. The material of which the banks are composed is not uniform, loam, clay, buckshot, and silt occurring in layers one above the other; frequently for a distance the bank is entirely of sand, and at other places silt; especially is this silt found in pockets between points of harder material jetting out from the shore. The result where hydraulic grading is the method practiced is a washing out of the lower part of the slope in holes where composed of sand or silt, breaking down of the outside edge of the grade, and sloughing off next the water. In order not to retard the progress of the work, these holes are necessarily filled up with loose material, with no time for settlement.

Again, the great quantity of water pouring down the slope thoroughly saturates the lower part, and leaves it in anything but a proper condition as a foundation for riprap.

The banks in many places are 30 feet or more in height, with an irregular face, approximating 1 on 1. The cables which are woven in the mat, and pass over the top of the bank where the mat is sunk, become loose as the grading proceeds, and afford no resistance to the sliding out of the mat, at a time when it is subjected to an enormous strain from the slipping down under the mat of the material that is washed from the bank in a semi-fluid condition. These cables can not be kept taut while the grading at the particular point is in progress, and the result the present season has been, where the material was soft, a sliding out of the mat and parting of the cables. This necessitates the building of new mats, adding materially to the cost of the work. The diagram below will perhaps explain more clearly.



These are the principal practical objections to grading the upper slope after the mat is sunk in place, aside from the fact that this plan of work shortens the time when revetment work can be properly done. Inasmuch as the low-water season is of short duration, and it is only at low stage that grading of the upper bank can be carried on, the amount of revetment work that can be finished depends upon the length of upper bank that it is possible to grade before the river rises. And as the grading is necessarily the length of one mat, from 800 to 1,000 feet, behind (by reason of the space occupied by the head and mooring lines to the lower mat under construction), it is compulsory to stop mat building before the river begins to rise to any extent, in order to have sufficient time to grade and revet the slope in front of the last mat, or else leave this part of the work in an unfinished condition with the lower part of the bank slope nearly vertical.

Among the advantages of grading ahead of the mat construction are:

First. The graded bank allows the holding in cables to be permanently fastened before the mat is sunk in place, thus preventing any slipping or sliding out of the mat from the shore.

Second. The whole of the low-water season can be utilized for work in mat building; the mat construction and bank revetment can be carried up the graded slope as the river rises, thus allowing more work to be accomplished.

Third. It provides a regular slope for the upper part of the shore mat to rest on or for the brush revetment to be placed, which, covering the loose material with which the holes in the lower slope made in grading are filled, gives the stone with which the slope is covered when completed a better support, and prevents it sinking into the soft earth.

Fourth. It insures better work.

GENERAL REMARKS.

The weakest part of revetment work is at or near the low-water line. By the construction of a shore mat as proposed, a double thickness of mattress is placed at the point where a break in the work might be anticipated, and strength therefore most needed, besides affording a foundation for the stone on the lower part of the slope, where the material is saturated and soft. The overlapping of the main mattresses on the shore mats forms a footing or abutting course, as it were, to prevent the slipping of the stone down the revetment below the low-water line.

The cribbing up of the upper and lower ends of the main mattress as a foundation, and the constructing of the low dikes at the foot of the slope, can be readily and economically done while the mat building is going on.

From a careful examination of the profiles of the Greenville dikes, and a number of sections in caving bends, it is believed that at the point where the grade of the river bottoms changes to the more abrupt grade of the caving bank, a system of low dikes of the profile proposed would have a good effect.

There is always danger, to a greater or lesser extent, in building and sinking mats 300 or 350 feet wide in a rapid current, where the length exceeds 500 or 600 feet. The length of the proposed mats is within these limits, and under ordinary circumstances there should be absolutely no danger of loss.

Leaving out the riprap on the upper 20 feet of the slope would save for a mile of work about 3,260 cubic yards of stone; taking cost of this at $2.50 per cubic yard and the cost of placing same at 40 cents, the total saving per mile would be $15,312.*

There can be no possible danger to the stability of the work in leaving this part of the bank unprotected, provided that the lower part of the slope is held; as the result of wave-wash would merely bring the slope to a water grade, and caving above this point, even if the bank was left vertical, could do no injury to the revetment underneath it.

More work can be accomplished by doing the grading first, while at the same time it will be left in a finished condition at the end of the working season.

The general results to be anticipated from revetment constructed as above would be due to a series of low dikes placed 500 feet apart, extending 250 feet beyond low water, with a continuous mattress between them. The upper slope covered with riprap 10 inches thick to within 5 feet of the top of the bank, and a double thickness of mattress extending from the zero line to a point 50 feet beyond. It is believed that this constructing will hold the bank in the worst caving bends.

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* This should be $9,454. (C. B. C.)

An approximate estimate of cost is given below for each 1,000 linear feet of completed work:

3,400 cords brush, at $1.10		$3,740.00
650 cords poles, at $1.50		975.00
6,450 cubic yards stone, at $2.50		16,125.00
26,000 pounds ⅝-inch wire cable, at 4 cents		1,170.00
3,0000 pounds wire, at 4 cents		1,200.00
8,000 pounds spikes and staples, at 4 cents		320.00
		23,530.00
Cost of labor and towing estimated at 40 per cent. of cost of work		15,686.66
		39,216.66
10 per cent. added for contingencies		3,921.66
Total estimate cost		43,138.32
Cost per linear foot of completed work		43.00
Cost per mile of completed work		227,040.00

Estimate of actual cost of material, labor, and subsistence in building crib-dikes at Greenville, Mississippi, September and October, 1889.

DIKE No. 1.

[Foot mat No. 1, 250 feet long by 175 feet wide = 43,750 square feet.]

Item.	Cost per unit.	Cost.	Per 100 square or cubic feet. Item.	Cost.
Brush, 400 cords	$1.27½	$510.00	0.914 cord.	$1.17
Poles, 27 cords	1.47½	98.82	0.513 cord.	.22
Stone, 708 tons	1.50	1,062.00	1.616 tons	2.43
Wire, 40 coils	3.37	134.80	0.091 cord	.31
Cable, 7½ coils	42.27	317.02	0.017 cord	.72
Spikes, 6-inch, 2 kegs	3.25	6.50		
Spikes, 9-inch, 6½ kegs	3.12½	20.31	0.019 keg	.06
Staples, 1 keg	5.00	5.00	0.002 keg	.01
Total		2,154.45		4.93
Construction, 4,068 hours	.17	*691.56	9.30 hours	1.58
Sailor work, 1,327 hours	.17	*310.59	4.18 hours	.71
Total		1,002.15		2.29
Grand total		3,156.60		7.22

* Including subsistence.

[First crib, 240 feet long by 32 feet wide by 8 feet high = 61,440 cubic feet.]

Brush, 184 cords	1.27½	234.60	0.299 cord	.38
Poles, 165 cords	1.47½	243.37	0.268 cord	.40
Stone, 378½ tons	1.50	567.75	0.616 ton	.92
Wire, 37 coils	3.37	124.69	0.060 coil	.20
Cable, 3½ coils	42.27	147.94	0.006 coil	.24
Spikes, 6-inch, 1 keg	3.25	3.25		
Spikes, 9-inch, 10 kegs	3.12½	31.25	0.018 keg	.06
Staples, ½ keg	5.00	2.50	0.001 keg	.00
Total		1,355.35		2.20
Construction, 2,932 hours	.17	*498.44	4.77 hours	.81
Sailor work, 999 hours	.17	*169.83	1.62 hours	.27
Total		†668.27		1.08
Grand total		2,023.62		3.28

* Including subsistence.

† Owing to high water running, drift, and unreliable labor, this is much in excess of what it should be.

Estimate of actual cost of material, labor, and subsistence, etc.—Continued.

DIKE No. 1.—Continued.

[Second crib, 190 feet long by 16 feet wide by 6 feet high = 18,240 cubic feet.]

Item.	Cost per unit.	Cost.	Per 100 square or cubic feet.	
			Item.	Cost.
Brush, 64 cords	1.27½	81.60	0.351 cord	.45
Poles, 63 cords	1.47½	92.92	0.345 cord	.51
Stone, 102½ tons	1.50	153.75	0.562 ton	.84
Wire, 25 coils	3.37	84.25	0.137 coil	.46
Cable, 2 coils	42.27	84.54	0.011 coil	.46
Spikes, 6-inch, 1 keg	8.25	8.25		
Spikes, 9-inch, 6 kegs	3.12½	18.75	0.038 keg	.12
Total		519.06		2.84
Construction, 1,331 hours	.17	*226.27	7.30 hours	1.24
Sailorwork, 582 hours	.17	98.94	3.19 hours	.54
Total		325.21		1.78
Grand total		844.27		4.62

*Including subsistence.

[Revetment No. 1, 25,000 square feet.]

Brush, 318 cords	1.27½	405.45	1.272 cord	1.62
Poles, 51 cords	1.47½	75.22	0.204 cord	.30
Stone, 710 tons	1.50	1,065.00	2.840 tons	4.26
Wire, 27 coils	3.37	90.99	0.108 coil	.36
Spikes, 5 kegs	3.12½	15.62	0.020 keg	.06
Total		1,652.28		6.60
Construction, 3,281 hours	.17	*557.77	13.12 hours	2.23
Grading, 878 hours	.17	149.26	3.51 hours	.60
Total		*707.03		2.83
Grand total		2,459.31		9.43

*Including subsistence.

[Spur No. 1, 20,000 cubic feet.]

Brush, 45 cords	1.09	49.05	0.225 cord	.25
Poles, 35 cords	1.48	125.80	0.425 cord	.63
Stone, 97 tons	1.95	189.15	0.485 ton	.95
Wire, 10 coils	3.37	33.70	0.050 coil	.17
Total		397.70		2.00
Construction, 707 hours	0.17	*120.19	3.53 hours	.61
Grand total		517.89		2.61
Cost of entire dike No. 1		9,001.69		

*Including subsistence.

Estimate of actual cost of material, labor, and subsistence, etc.—Continued.

DIKE No. 2.

[Foot mat No. 2, 290 feet long by 290 feet wide = 84,100 square feet.]

Item.	Cost per unit.	Cost.	Per 100 square or cubic feet.	
			Item.	Cost.
Brush, 553 cords	1.27½	705.07	0.657 cord	.84
Piles, 141 cords	1.47½	207.97	0.168 cord	.25
Stone, 767 tons	1.95	1,496.65	0.912 ton	1.78
Wire, 34 coils	3.37	114.58	0.040 cord	1.36
Cable, 6 coils	42.27	253.62	0.007 cord	.30
Spikes, 6-inch, 4 kegs	3.25	13.00		
Spikes, 9-inch, 5½ kegs	3.12½	15.63	0.011 keg	.03
Staples, 1¼ kegs	5.00	6.25	0.001 keg	.01
Total		2,811.77		4.57
Construction, 5,630 hours	.16	*900.80	6.69 hours	1.07
Sailor work, 737 hours	.16	*117.92	0.88 hour	.14
Total		1,018.72		1.21
Grand total		3,830.49		5.78

*Including subsistence.

[First crib, 212 feet long by 33 feet wide by 8 feet high = 54,272 cubic feet.]

Brush, 228 cords	1.27½	290.70	0.420 cord	.54
Poles, 100 cords	1.48	148.00	0.184 cord	.27
Stone, 324 tons	1.50	486.00	0.597 ton	.90
Wire, 32 coils	3.37	107.84	0.059 cord	.20
Cable, 2½ coils	42.27	105.67	0.005 cord	.20
Spikes, 6-inch, 2½ kegs	3.25	8.94		
Spikes, 9-inch, 7½ kegs	3.12½	24.22	0.019 keg	.06
Total		1,171.37		2.17
Construction, 2,686 hours	.16	*429.76	4.95 hours	.79
Sailor work, 610 hours	.16	*97.60	1.12 hours	.18
Total		527.36		.97
Grand total		1,698.73		3.14

*Including subsistence.

[Second crib, 170 feet long by 16 feet wide by 8 feet high = 21,760 cubic feet.]

Brush, 95 cords	1.27½	121.12	0.437 cord	.55
Poles, 52 cords	1.48	76.96	0.239 cord	.35
Stone, 119 tons	1.95	232.05	0.547 ton	1.07
Wire, 27 coils	3.37	90.99	0.124 coil	.42
Cable, 1½ coils	42.27	63.40	0.007 coil	.29
Spikes, 6 inch, 1½ kegs	3.25	5.69		
Spikes, 9 inch, 2½ kegs	3.12½	7.03		
Spikes, 9 by ⅞ inch, 1½ kegs	5.70	8.55	0.005 keg	.09
Total		605.79		2.77
Construction, 1,351 hours	.16	*216.16	6.21 hours	.99
Sailor work, 310 hours	.16	*49.60	1.42 hours	.23
Total		265.76		1.22
Grand total		871.55		3.99

*Including subsistence.

Estimate of actual cost of material, labor, and subsistence, etc.—Continued.

DIKE No. 2.—Continued.

[Revetment No. 2, 23,000 square feet.]

Item.	Cost per unit.	Cost.	Per 100 square or cubic feet.	
			Item.	Cost.
Brush, 325 cords	1.09	354.25	1.413 cords	1.54
Poles, 45 cords	1.48	66.60	0.196 cord	.29
Stone, 669 tons	1.95	1,265.55	2.852 tons	5.50
Wire, 22 coils	3.37	74.14	0.096 coil	.32
Spikes, 6-inch, ½ keg	3.25	1.62		
Spikes, 9-inch, 3 kegs	3.12½	9.37		
Spikes, 9 by ½ inch, ½ keg	5.70	2.85	0.017 keg	.06
Total		1,774.38		7.71
Grading, 5,000 hours	.16	*800.00	21.74 hours	3.48
Construction, 3,584 hours	.16	*573.44	15.58 hours	2.58
Total		1,373.44		6.06
Grand total		3,147.82		13.77

*Including subsistence.

[Spur No. 2, 3,000 cubic feet.]

Brush, 7 cords	1.09	7.63	0.233 cord	.25
Poles, 10 cords	1.48	14.80	0.333 cord	.49
Stone, 16 tons	1.95	31.20	0.533 ton	1.04
Wire, 2 coils	3.37	6.74	0.066 coil	.22
Total		60.37		2.00
Construction, 202 hours	0.16	*32.32	6.073 hours	1.08
Grand total		92.69		3.08
Cost of entire dike No. 2		9,661.28		

*Including subsistence.

Care of fleet, pumping, etc., 5,000 hours, at 17 cents	*$855.10
Coaling *Vidalia* and pile-driver, 979 hours, at 17 cents	*166.43
Digging dead men, pulling drift, etc., 469 hours, at 17 cents	*79.73
Helper for carpenter, 304 hours, at 17 cents	*51.68
Total	1,152.94

*Including subsistence.

Cost of subsistence.

1889.	Ration raw.	Ration served.	Labor secured.
	Cents.	*Cents.*	*Cents.*
September	29½	40½	43½
October	29½	34½	36½
November	30½	44½	46½

FINANCIAL STATEMENT.

Greenville Reach.

May 31, 1889. Balance allotment act of August 11, 1888		$33,595.64
Expended to May 31, 1890, for—		
Labor on construction	$8,078.22	
Material for construction	10,178.77	
Subsistence	3,806.97	
Cost plant, repairs, and outfit	870.28	
Care of public property	4,463.60	
Towage and steamer expenses	2,002.70	
Administration and office expenses	128.31	
Surveys	582.06	
Miscellaneous	2.25	
		30,113.16
Balance in hand June 30, 1890		3,482.48
Less liabilities		586.33
Available balance June 30, 1890		2,896.15
Amount that can be profitably expended in fiscal year ending June 30, 1892		350,000.00

LAKE BOLIVAR FRONT.

A special allotment for this work was made by the river and harbor act of August 11, 1888. The object of the improvement is to stop the caving of the bank in front of the large and costly levee across the end of Lake Bolivar, which was being threatened by the rapid encroachment of the river. During the latter part of 1888 and the beginning of 1889, a part of the bank immediately in front of this large levee was revetted.

The details of this work are set forth in the annual report of the Chief of Engineers for 1889, pages 2704 *et seq.*

This work, so far as carried out, was perfectly successful in stopping caving. Below the work, the bank is still caving rapidly, and the revetment will probably have to be extended down-stream for a considerable distance.

The operations at Lake Bolivar front during the year ending May 31, 1890, consisted simply in repairing some of the revetment constructed during the previous year. The details of the work are fully set forth in the following report of Mr. H. St. L. Coppée, assistant engineer, who was in local charge of the repair work.

The present condition of the work is unknown, as the river is still too high to permit an examination to be made.

REPORT OF MR. H. ST. L. COPPÉE, ASSISTANT ENGINEER, ON WORK DONE DURING THE YEAR ENDING MAY 31, 1890.

October 24 I made an examination of the bank of the river in the vicinity of Bolivar Landing, Miss., and, but for the need of a little rock, found pretty much the entire revetted bank in good shape, except at a point where the Bolivar Warehouse stood; also at the lower end of the work of 1888. It may be well to state here that in that year 4,400 lineal feet of mattress-work and 4,250 feet of revetment was built along this front to keep the river from caving into the large levee across Lake Bolivar, thus exposing the back country to excessive overflow at high water and seriously deranging the regimen of the river in that vicinity. (See report of Chief of Engineers, 1889, page 2704.)

At the warehouse my examination showed that the old broken-up revetment would have to be taken off the bank and the bank graded. Near the lower end of the work I found the revetment again badly broken, and reported that little could be done there with the small means allowed, but put new revetment on the bank in places over the old. The mattress-work seemed to be intact all along the revetted bank to the very end, where it was considerably broken up and where it was proposed to do the patch-work by sinking a mattress.

We were troubled at this point again by inability to obtain or keep reliable labor; men would come to the locality, but after working four or five days would leave in large numbers, placing operations practically at a standstill. November 1 work commenced here and was carried on continuously till November 26, with the same plant and force of foremen, etc., used at Greenville. The rock used in construction was obtained from the piles of rock stored at Bolivar in 1888.

November the 9th, I was instructed to send my steam-boat, the *Vidalia*, to Ashton, where more extensive work was in operation, and where, unfortunately, their tow-boats were all broken down, thus practically stopping the work of over 500 men. At the time the river was rising, my mooring barges and mat-boats were in place, and a very small part of the lower mat, shown in accompanying map, was built. I had hoped to construct and sink the mat before the river reached such a height as would make the work dangerous and difficult, but owing to the absence of the steam-boat, which was detained about a week, the conditions were very unfavorable when the mattress was being completed.

The mattress was finished and ready to be sunk November 21. It was 244 feet long by 240 feet wide. There was 500 feet of drift piled in front of it, 350 feet wide, and probably 20 feet deep. This latter proved too great a strain during the process of sinking; every line and cable (17 in all) broke, and the mat drifted down the river retaining its normal shape, but we were unable to fasten it to the bank at any point.

As the portion of the bank this mattress was to occupy was to some extent protected, and as it was supposed to have been built at low water and extend further out into the river than the old work, and also on account of the fact that the water was rising above, it was deemed expedient to give up all idea of a mattress at that point that season. The other work, consisting of a foot-mat and revetment, is shown in accompanying sketch. The foot-mat is 255 feet long by 65 feet wide, the revetment 270 feet long by 42 feet wide. The grading was done in the same manner as that at Greenville.

In order to thoroughly protect the lower end of this reach, and make the work permanent, at least half a mile of the strongest kind of revetment should be placed on the bank from the warehouse down the river, and a thorough system of drainage established, if possible, to do anything with the sloughing caused by seep water from adjacent holes and lakes. The approximate cost of putting this work in good condition and extending it as stated, say 2,000 feet down the river, would be $100,000. This would include adding considerable rock to the revetment completed in 1888.

The material, with the exception of rock, was obtained from the same source and at the same place as for the Greenville Reach.

Cost of material, labor, and subsistence in building mat and revetment at Bolivar, 1889.

[Deep-water mattress, 235 by 244 feet wide, 57,340 square feet.*]

Items.	Cost per unit.	Total cost.	Per 100 square feet.	
			Item.	Cost.
Brush, 352 cords	$1.27½	$448.80	.614 cord	$0.78
Poles, 83 cords	1.47½	122.42	.145 cord	.21
Stone, 225 yards	2.30	517.50	.393 yard	.90
Wire, 34 coils	3.37	114.58	.059 coil	.20
Cable, 6½ coils	42.27	274.75	.011 coil	.47
Spikes (6-inch), 2½ kegs	3.25	8.12		
Spikes (9-inch), 2½ kegs	3.12½	7.81		
Spikes (9½-inch), 3¾ kegs	5.70	18.52	.014 keg	.06
Staples, ¾ keg	5.00	3.75	.001 keg	.01
		1,516.25		2.63
Construction, 4,292 hours	.17	†729.64	7.49 hours	1.27
Sailor work, 977 hours	.17	†166.09	1.71 hours	.29
Total		895.73		
Grand total		2,411.98		

Cost of material, labor, and subsistence in building mat, etc.—Continued.

[Foot mat, 255 by 65 feet wide, and revetment 270 by 42 feet wide, 16,575 + 11,340 = 27,915 square feet.]

Items.	Cost per unit.	Total cost.	Per 100 square feet.	
			Item.	Cost.
Brush, 178 cords	$1.27½	$226.95	.638 cord	$0.81
Poles, 36 cords	1.47½	53.10	.129 cord	.19
Stone, 561 yards‡	2.30	1,290.30	2.011 yards	4.62
Wire, 20 coils	3.37	67.40	.072 coil	.24
Cable, 2½ coils	42.27	91.58	.008 coil	.34
Spikes, 1½ kegs	3.25	5.69		
Spikes, 1 keg	3.12½	3.12		
Spikes, 1¾ kegs	5.70	9.97	.016 keg	.07
Staples, ¼ keg	5.00	1.25	.001 keg	
		1,749.36		6.27
Construction, 2,794 hours	.17	†474.98	10.01 hours	1.70
Sailor work, 194 hours	.17	†32.98	.69 hour	.16
Clearing and grading, 4,180 hours	.17	†710.60	14.98 hours	2.55
Total		1,218.56		4.41
Grand total		2,967.92		10.68

* This mat was lost in sinking, which accounts for small amount of stone used.
† Includes subsistence.
‡ About 75 yards of this stone used on old revetment.

Care of fleet during whole work, 1,926 hours, at 17 cents	$327.42
Loading 1,310 yards stone on barges, 4,024 hours, at 17 cents	684.08
Moving drift during work, 480 hours, at 17 cents	81.60
Coaling steamer during work, 273 hours, at 17 cents	46.41
Grinding axes, etc., during work, 166 hours, at 17 cents	28.22
	1,167.73

Cost of subsistence.

Ration, raw	$0.40
Ration, served	.46
Ration served in proportion to labor secured	.54

FINANCIAL STATEMENT.

May 31, 1890, balance allotment, act of August 11, 1888		$47,511.49
Expended to May 31, 1890	$12,221.77	
Transferred to surveys, examinations, and inspections, third district	4,000.00	
Transferred to surveys, examinations, and inspections, fourth district	3,000.00	
Transferred to protection of levees, fourth district	3,000.00	
Transferred to protection of levees, third district	5,000.00	
		27,221.77
May 31, 1890, available balance		20,289.72
Of which in hand	289.72	
In Treasury	20,000.00	
		20,289.72

There are no liabilities.

Expenditures apportioned for—	
Labor on construction	$3,513.41
Material for construction	3,227.15
Subsistence	1,978.43
Cost plant, repairs, and outfit	355.21
Care of public property	778.09
Towage and steamer expenses	1,779.17
Administration and office expenses	96.00
Surveys	398.91
Medicines and medical attendance	85.00
Miscellaneous	10.40
Total	12,221.77
Amount that can be profitably expended during fiscal year ending June 30, 1892	100,000.00

HIGH-WATER PROTECTION OF LEVEES AND THE FLOOD OF 1890.

The high stage of the river in January seemed to indicate that an annual flood of considerable magnitude would obtain. A natural general curiosity was excited in anticipating the effect of the new Arkansas levees. For the first time in a number of years a continuous line of levees existed on both sides of the river, and, if as was expected, this should prove a flood year, it was of the greatest importance that these levees should be held, in order that their effect in scouring out the bed of the river might be determined. There seemed to be a general determination to hold the levees, if possible, on the part of the Mississippi River Commission, the different State levee boards, and the people generally.

The funds in my hands at this time for levee protection work amounted to $18,701.50 only. Since the State levee boards of Mississippi and Louisiana were pushing levee work vigorously, and seemed to have plenty of funds on hand, while nothing whatever was being done in Arkansas, I thought it best to confine operations to the Arkansas line alone. Accordingly, Assistant Engineer Tollinger, who had been engaged for several years on the Arkansas levees, and who was more familiar with their then condition than any one else, was sent to make a careful examination of the whole line; to repair and strengthen the weakest parts where danger actually existed, so far as the funds would permit; and to arrange for such thorough inspection of the line as might be needed during high water.

A force of hired teams was put to work raising the large and important Whisky Chute and Grand Lake levees which had settled, the former to 5 feet and the latter to 3½ feet above the high water of 1888.

Early in March the flood had attained alarming proportions, and the high stages of the Ohio River and its tributaries, from which the flood mainly proceeded, together with the persistent and long-continued high water in White River, seemed to threaten a flood that would overwhelm the levees and spread general disaster if the most heroic efforts were not made to strengthen and raise the levees. Alive to the danger, General Comstock, president of the Commission, took prompt steps to have the necessary funds provided for protection work, and accordingly $25,000 were transferred to the protection fund on March 11, $32,000 on March 18, and $27,250 on March 21.

Before these transfers were made the people of Arkansas, upon the persistent solicitations of United States Assistant Engineer Tollinger, and especially after they realized the danger threatening them, contributed liberally and worked manfully in holding their line.

Hard and expensive fights were being made by the board of Mississippi levee commissioners, and especially by the board of the fifth Louisiana levee district, in holding their respective lines.

Had it not been for the very energetic and heroic work of the several State levee organizations, supplemented by the timely and liberal assistance rendered by the General Government, a very considerable portion of the levee line would have been breached, and the overflow would have been much more general and disastrous than it proved. I do not think it an exaggeration to say that 50 miles of levee in the third district would have been overtopped by the flood had not the levees been hurriedly raised by topping, or with sacks filled with earth. In some instances the line was held by a sack wall, where the water was fully 2 feet higher than the top of the levee.

As soon as the transfer of funds for levee protection purposes was made, it was decided, in the absence of instructions on the matter, that assistance should be given wherever needed within the limits of the district, whether on one side of the river or the

other, and without considering whether the levees had been built by the United States, by the State levee boards, or by private corporations and individuals. The presidents of the several State levee boards and their engineers were seen at once, and told that any assistance they might need would be cheerfully and promptly furnished.

The work in Arkansas, as had been done before, was continued under direct Government supervision.

It was suggested by me that, in continuing the work in Mississippi and Louisiana, the State levee organizations should pay for all labor, while the Government should furnish all material, such as sacks, bagging, lumber, etc., needed to protect the levees.

This arrangement was agreed to, and for a time was carried out, but towards the end of March the funds of the Louisiana board were so nearly exhausted that it became necessary for the Government to assume complete charge of all protection work in that State, which was accordingly done, Mr. Henry Goodrich, assistant engineer, being placed in immediate charge.

No assistance in labor was asked for or furnished in Mississippi except at the crevasses, where the work of protecting ends of broken levees was paid for by the United States. By agreement this work was done under the immediate supervision of the chief engineer of the Board of Mississippi Levee Commissioners, Maj. William Starling.

Detailed accounts of the work done in the third district since January in protecting the levees from flood; in gauging the discharge of the river at Wilson's Point, La., and at Arkansas City; in gauging the discharge at the several crevasses; in establishing high-water marks; in determining the extent of country overflowed; in attempting to close the Offutt Crevasse; in protecting the ends of broken levees at other crevasses, and in removing people and stock from flooded districts are given in the following reports of assistants.

All the data collected respecting the flood is given in these reports, or in the tables, statements, and drawings following.

During my absence from the river, in office work at Memphis, the general supervision of the work of levee protection in the third district was intrusted to Mr. Arthur Hider, assistant engineer. His administration of the work was at all times characterized by energy, intelligence, loyalty, and good judgment. He was ably assisted by Mr. E. C. Tollinger, assistant engineer in charge of the Arkansas levees, and by Mr. Henry Goodrich, assistant engineer in charge of the Louisiana levees, and to all these gentlemen the greatest credit is due.

During the continuance of the flood I made a number of trips on the river from Memphis to Vicksburg. I could not help noticing that the trade along the river was almost completely paralyzed during the overflow. The conviction was forced upon my mind that an improvement of the river for high-water navigation was quite as important and necessary and of vastly more general benefit than an improvement for low-water navigation alone. By a high-water improvement I mean such control of the flood waters as shall surely protect the country from overflow and allow business to be carried on along the banks of the river during the whole season of high water.

This can not be done without the aid of levees, and therefore I regard it quite as much the duty of the General Government to build levees as it is to revet banks or build dikes. If levees are not built to restrain the floods and prevent overflow by the Government, by the States, or by individuals, it may well be doubted if the benefits to be derived from a low-water improvement of the river in the manner now being carried out by the Mississippi River Commission will justify the cost. On the other hand, if the Government shall aid in building such levees as will give security against overflow, there will be a great development of the whole Delta country, a large part of which is now virgin forest, and the commerce and trade of the river will be wonderfully increased.

This hope alone can, in my mind, justify the expenditure of the vast sums of money that will be needed to in any way effectually and surely improve the navigation of the river.

An effort has been made to collect and furnish as full data as possible respecting the flood; but no study or discussion of it has been attempted by me, both for lack of time and because, doubtless, a full discussion and report on the flood will be made by the Commission, from the information furnished from this and other districts, supplemented by data collected from other sources.

REPORT OF MR. ARTHUR HIDER, ASSISTANT ENGINEER, ON THE HIGH-WATER PROTECTION OF LEVEES AND THE FLOOD OF 1890.

The steady rise of the river in February, which, at the beginning of the month was only 2 feet below the highest recorded water at Greenville, caused apprehension in regard to the safety of the Arkansas levees. A thorough inspection of the line was

made, and work done on some of the weakest places. As only a small balance was at that time available, but little work could be done, and this only where the needs were most urgent. The river rose steadily, until, near the end of the month, it had reached the highest previously recorded water at Greenville, and the danger of a flood became imminent.

The flood of 1890, while not reaching the extreme height of previous floods at Cairo, has at several points in the third division exceeded the heights of any previously recorded high water.

The fact of a continuous line of levees being in existence on both sides of the river for the first time for a number of years, will cause this flood to be classed in the list of the great floods, so far as this particular section is concerned, as the height of the water between the levees, by reason of its being confined, exceeded that of previous years, and the crevasses that occurred on both sides of the river when the flood was nearly at its maximum, caused a wide-spread and disastrous overflow.

This flood exceeded in height the floods of 1882, 1884, and 1886 by 2.3 feet at Arkansas City, 1.7 feet at Greenville, 3.1 feet at Wilson's Point, and 0.1 foot at Vicksburg.

The limits of the overflow caused by crevasses have been obtained from a reconnaissance made of the localities inundated, and are approximately correct. Parties were sent out on each side of the river to trace the line of backwater.

The plantations everywhere, except in a few places located on the highest ridges, were entirely submerged, and while a less extent of territory has been overflowed than in 1882, the damage to stock and property has been very great, and the lateness of the season will prevent, in many cases, the possibility of raising a crop after the water subsides. This will render the actual damage inflicted on the community in the overflowed district fully as great as that of any previous flood.

The limits of the land submerged are given below:

Right bank.—From the mouth of the Arkansas River the backwater came close up to the levees as far down as Sunnyside, from there to Bedford at the lower end of the district, there was a narrow strip of land (except in the vicinity of the Raleigh Crevasse) close to the river bank, from 1 to 8 miles wide, which was not submerged.

The western limits of the overflow extended up the Arkansas River to Millwood, crossing the Little Rock, Mississippi River and Texas Railroad about a mile below Varney, and skirting along the upper side of Wells, Choctaw, and Amos bayous; it then crossed Amos Bayou and ran in a southerly direction to Tillar, 18 miles west of Arkansas City, thence following the railroad embankment to within 3 miles of Trippe Station, thence south along the high ground between Bayou Bartholomew and Bœuf River to the Ouachita River, about 15 miles below Monroe. The high ground between Bayou Macon and Bœuf River, from as high up as Lakeport, was not overflowed.

This strip has an average width of 5 miles.

The counties overflowed in Arkansas were the northeast portion of Lincoln, the greater part of Desha, nearly all Chicot, and a small part at the southeast corner of Ashley County.

In Louisiana, more than one-half of East and West Carroll, the eastern part of Moorhouse and Ouachita, and portions of Richland, Franklin, and Madison Parishes were submerged. The country overflowed within the above limits contains 3,050 square miles.

Within these boundary lines, 560 square miles of land was high ground above overflow, or about 15¼ per cent.

Left bank.—The upper limit of the back water is in the vicinity of the town of Bolivar, and from there follows in a southeasterly direction to the Yazoo River.

Nearly all the ground west of this line was inundated to a depth of from 1 to 6 feet; this area embraces the southwest portion of Bolivar County, nearly all of Washington County west of the Sunflower River, a small portion of Sunflower County, all of Isaquena County, and, with the exception of a strip of land along the Louisville, New Orleans and Texas Railroad, all of Sharkey County, that part of Warren County which lies west of the Yazoo River, as well as a large portion of Yazoo County itself, which is west of the Yazoo River.

The above territory embraces an area of about 1,978 square miles, and, except about 89 square miles, or about 4.4 per cent. on the highest ridges, was completely submerged.

A map showing the limits of the overflow within the district, plate 2, is submitted herewith.

During the months of March and April, the river remained at flood height.

Such portions of the working plant as could be used to advantage were employed in transporting material to various points in the district, where most needed for strengthening and raising the levees, giving shelter to overflowed people, and moving people and stock to places of safety.

Forces were put on at critical points, and worked in connection with other forces employed by the local levee boards.

The United States steamers *Emma Etheridge*, *Osceola*, and *Vidalia* were put in service with double crews, the *Osceola* being engaged after the 15th of March almost entirely on the levees in the fifth Louisiana levee district, the *Vidalia* at Arkansas City, and the *Etheridge* in general work along the entire line. The *Vidalia* broke her shaft on March 20, and the *R. A. Speed* was chartered in her place. The *H. M. Graham* was obtained from the second district. Both these boats were constantly employed during the emergency of the flood.

Inspectors were placed all along the Arkansas front, as it was considered that, on account of the low grade and small section of many of these levees, more work would be needed here than elsewhere, while at the same time the local organizations in this State were not nearly so strong as those in Louisiana or Mississippi.

Assistance in the way of material, sacks, lumber, and the use of plant, to aid in raising and strengthening levees, was given to the levee authorities on both sides of the river whenever called for, and as promptly as possible.

In the beginning, the forces of laborers were paid by the local levee boards and the work was directed by the inspectors. When the situation became more critical and the funds of the local boards for protection purposes had been nearly exhausted, these forces on both sides of the river were worked and paid entirely by the United States.

A quarter-boat, to afford temporary shelter to overflowed negroes, was left at Chicot, Ark., and also one at Skipwith's, Miss., after the break in the levee at that point; these were of great service to the people who were overflowed.

Prompt assistance was rendered by the United States steam-boats in removing people and stock to places of safety.

Five barges of stock were towed from the vicinity of Mound and Huntington crevasses to Arkansas Post, and some three hundred people who had been overflowed were taken to places of safety, either at Arkansas City or at Arkansas Post.

The following is a list of the boats employed in levee protection and in giving assistance to people suffering from the overflow: 6 steam-boats, 4 quarter-boats, 7 pile-drivers, 12 barges, 1 mat boat, besides 35 skiffs and small flats.

All the employés have shown a commendable interest in the special work intrusted to their charge and have rendered valuable and efficient service both to the work and also to the general community.

CREVASSES.

The first crevasse in the levees occurred March 9, at Sappington, 9 miles above Arkansas City, and was caused from the water forcing itself through the levee near the base.

From the best information obtainable, the crevasses at Catfish Point, Easton or Mound, Huntington, Offutt's, and Skipwith's, in Mississippi, and that at Raleigh, La., happened in a similar manner.

The long continued pressure of water against the levees caused them to become thoroughly saturated, and the porous material which constitutes, in a great many instances, the foundation of these levees, aided by the location of borrow pits and side ditches near the base, permitted the percolation of water through the levees at and below the natural surface of the ground, thus allowing the hydrostatic pressure caused by the head of water in front to be transmitted to the land side beyond the base, causing an upheaval of the ground and permitting a flow of water through or under the levee, thus causing a break.

The crevasses in Opossum Fork Levee, between Boggy and Amos Bayous, Furguson's, 2 miles above Chicot, near Chicot, 2 miles above Arkansas City, and at Luna, Ark., were from settlement of the levee, due to saturation and imperfect foundations, as shown by longitudinal cracks, which appeared first in the crown of the levee, followed by a sloughing off of part of the back slope.

This sloughing continued until the section of levee itself had become too weak to resist the pressure of water against the front, and the levee broke.

The breaks in the levees around Point Chicot occurred on March 5 and 6, when the river was 1.8 feet below its highest point, and were caused by insufficient height.

The break in the Leeland Loop Levee, below Columbia, took place during a storm, and was from insufficient section, as well as height.

The Opossum Fork Levee, where it is crossed by Boggy Bayou, was purposely cut by parties living above under the impression that it would afford relief to them from the back-water.

The remedy to prevent a recurrence of these disasters in the future suggests itself:

(1) A greater height of embankment.

(2) A larger section.

(3) More care in selection of material and in details of construction of the foundation.

(4) The additions of a berm on the land side, where the material is porous, to give the necessary weight and stability to counteract the water pressure from the river side.

The Offutt's crevasse, which occurred on March 18, was the first break in the Mississippi levees.

As instructed by you, on March 21 a force was organized, material procured, four pile-drivers put in service, and work begun on the 23d in driving piles to close the crevasse. The plan was to drive a double row of piles across the break about 5 feet apart, the distance between the rows of piles to be one and one half times the depth of water, sheet piling 2 by 6 inches to be driven in front.

It was intended to use brush to prevent scour in front, and, behind the sheet piling between the rows of piles, to fill up solidly with sacks of earth.

The depth of water was from 7 to 14 feet. The work was well under way, with the promise of a successful termination, when, on the night of the 27th, the crevasses at Huntington and Mound occurred.

The back water rose so rapidly from these breaks that it was evident that the closure of this crevasse would do little good toward preventing an overflow. The work was abandoned on the 29th and the plant moved elsewhere, after some 40 piles had been driven in place.

To prevent the crevasses from widening various plans were tried at different localities.

(1) Revetting the ends of the levees by stringing sacks filled with earth around the end of the broken levee, thus protecting the end from further scour.

(2) Making and sinking a pliable willow mattress along the outside, above the broken end, which, as the levee caved back, was wrapped around the exposed end by the action of the current.

(3) By building out a dike of brush and sacks or piles and brush above the broken end to deflect the rapid current flowing along the base of the levee and direct it through the gap more nearly perpendicular, and thus relieve the broken ends from the scouring action of the water.

The first plan, that of revetting with sacks of earth, failed in every instance in which it was tried, the end of the levee being constantly undermined while the work was being done, and notwithstanding constant renewals in not a single instance was any satisfactory or permanent result accomplished.

For a high levee, where the depth of the water flowing through is over 4 or 5 feet, this plan is not recommended, as it was given a fair trial in a number of instances.

The method of protecting the ends with a pliable willow mattress was tried at the Raleigh break, and, after repeated failures of the sack revetment method, at the upper end of the Skipwith break also. This plan was successful at the upper end of the Raleigh break, but required constant work and additions from day to day, as the scour along the base of the levee kept undermining the mat. At the lower end of the crevasse the mattress failed to hold the end; after the caving had extended down to the mat the undermining of the levee continued, and the result was that a great deal of extra work became necessary to prevent the crevasse widening.

At Skipwith's, after the mat had been sunk in place, from the experience at Raleigh it was thought advisable to supplement it by building a dike, jutting out from the levee, to stop the current flowing along the base.

Wherever dikes were used to deflect the water from the base of the levee the results were quite satisfactory, and after our unfavorable experience with the sack revetment (the plan heretofore usually followed) for protecting the ends of broken levees dikes were used.

These dikes were constructed in various ways, depending upon the locality, the difficulty of getting barges or pile-drivers to the crevasses, the kind of material available, or the particular locality suggesting difference in the details.

The object sought to be obtained was to stop the scour caused by the rapid current flowing along the base of the levee, and thus preventing the undermining and caving away of the ends.

A description, giving the details of the different constructions used, is given below.

Luna Crevasse.—In front of this crevasse was a growth of heavy timber which precluded the possibility of getting a pile-driver to the break. A number of large trees, close to and in front of the levee, were utilized in lieu of piles.

These were connected with wire cables, fastened around and leading from tree to tree; the cables were stretched at different heights above the ground, and against these cables brush was floated; this lodging against the cables and trees, formed a brush dike, deadening the current sufficiently to allow the building out of a dike made of sacks of earth immediately below the brush.

More brush was then added, and when finished there was constructed a solid dike

of sacks of earth, the front of which was protected with brush and small trees to prevent scour.

The dike was about 18 feet wide, and extended out from the levee about 70 feet, shielding about 100 feet of the levee below the dike, and directing the flow through the crevasse nearly at right angles to the levee, stopping the undermining and consequently further caving of the broken end of the levee. The same method was applied to the lower end. The result was entirely satisfactory, and no further work was needed.

Columbia Break.—This dike was made of a single row of piles driven from 15 to 20 feet in the ground, and spaced about 5 feet apart. The scarcity of brush in the vicinity and the lack of barges and towing facilities rendered some other plan advisable. Cypress plank 2 inches thick, and from 12 to 16 feet long, were spiked together, forming shutters about 10 by 16 feet. These were placed against the front of the row of piles, shutting off the flow sufficiently to allow the building of a solid dike of sacks of earth immediately below. Afterwards it was found necessary to float brush against the upper side to prevent scour along the front, and especially at the outer end of the piles.

The lower end of this crevasse was treated in the same manner; result, complete success.

Skipwith's Crevasse.—The lower end of this crevasse was secured by a dike built of sheet piles, driven by hand, re-enforced with sacks of earth. To protect the upper end a revetment of sacks around the broken end was repeatedly tried, but was as often undermined and carried away. A dike built out from the levee, composed of brush and filled sacks was then attempted; the first was scoured out and a second one constructed, but it was found impossible to carry the dike so built far enough out from the base of the levee on account of the depth of water, 27 feet, caused by scour through the borrow pits located close to the base of the levee, to be of any service in deflecting the current.

In a few days this second dike was undermined and carried away. Recourse was then had to a mattress. This was built of small-sized willows on a mattress barge about 50 feet above the broken end of the levee. Instead of weaving poles, and so as to render the mat more pliable, $\frac{3}{4}$ inch cotton rope was used to bind the willows together; sacks of earth in tiers were fastened on the mat to sink it, and the mat launched into the water, the current sinking it and holding it against the slope of the levee. As the levee caved back the mat swung around against the broken end, and afforded a partial protection against scour.

As the current along the slope of the levee was very swift, and the experiences elsewhere of mattresses not being entirely satisfactory, it was deemed advisable, to render the work entirely safe, to supplement it with a dike. A dike of piles and board shutters, similar to that built below Columbia, was put in, and no further caving took place. At the Sappington Crevasse the dikes were constructed of sacks of earth and rock and were successful in holding the ends of the broken levee.

Furguson Crevasse.—The north end was protected by a dike of sacks filled with earth, the south end by a dike of piles and a screen mat in front of the piles to deaden the current.

Brook's Field Crevasse—Opossum Fork Levee.—North end protected with dikes of sacks, south end revetted three times and each time the revetment was washed out.

Crevasse between Arkansas City and Chicot.—North end protected with dike of timber, filled in with sacks extending out from the levee about 40 feet. Three dikes of sacks built at the lower end washed away.

Chicot Crevasse.—Ends protected with dike of piles, sacks of earth, and brush.

Crevasse at Catfish Point.—Ends protected by dike of piles, sacks of earth, and brush.

Crevasse at Mound.—Ends protected by dikes of piles, sacks of earth, and brush.

Opossum Fork Levee at Boggy Bayou.—Ends protected by felling trees and building dike of sacks filled with earth.

At Huntington.—The breaks on the lower side of Catfish Point and the small break above Greenville, nothing was done to protect the ends, as, except on the lower side of Catfish Point, where the breaks were due to the backwater from the Catfish crevasse flowing across the point and overtopping the levee, little caving back of the ends took place after the breaks happened.

At Offutt's.—The sack revetment was given a number of trials and in each case was undermined and carried away.

At Raleigh Crevasse.—The ends were protected by mattresses with only partial success, as much additional work was required. From the experience of this season's work it has been demonstrated that the method of revetting the ends of broken levees with sacks of earth is not applicable where the current is swift and the water flowing through the crevasse deep.

Of the other two plans tried, that of revetting the broken ends with a willow mattress, or building dikes to deflect and direct the current through the crevasse, the mattress was found to be the most expensive and required constant care and contin-

ual work to keep up, while the dike method, in every instance where tried, proved a success.

The heights of the old levees, contiguous to the crevasses with an approximate estimate of the cost of closing the gaps to the new grade, is given in the following statement:

For levee protection purposes a large amount of material was used. The principal items are given below.

There remains on hand about 71,000 sacks, which were purchased but not used.

Sacks expended		440,000
Lumber	feet..	470,046
Twine	pounds..	2,520
Bagging	yards..	35,700

The labor cost of the forces was:

Month.	Pay-roll.	Subsistence.	Total.
February, 1890	$1,390.87	$77.44	$1,467.31
March, 1890	24,460.61	2,614.13	27,074.74
April, 1890	17,267.04	1,312.40	18,579.44
Total	43,118.02	4,003.97	47,121.99

Approximate cost of closing crevasses, third district, 1890.

Location of levees.	Extreme height.	Average height.	Old grade.	New grade.	Length to close break.	Cubic yards.	Approximate cost at 20 cents per cubic yard.
	Feet.	*Feet.*	*Feet.*	*Feet.*			
Catfish Point, Miss	16.0	10.6	3.2 above 1882	3.0 above old	7,515	267,940	$53,588
Catfish Point, (lower side, small breaks)	14.0	10.2	3.0 above 1882	3.8 above 1890	3,528	90,300	18,060
Easton's or Mound, Miss	14.0	12.0	3.0 above 1882	3.8 above old	5,000	251,570	50,314
Huntington, Miss	14.0	9.9	5.0 above 1888.	3.8 above old	3,000	85,570	27,114
Offutt's	13.0	10.1	3.0 above 1888.	3.0 above old	3,000	74,690	14,938
Small break above Greenville.				3.0 above 1890.	300	5,960	1,192
Skipwith's, Miss	16.3	8.4	5.0 above 1888.	3.6 above old	4,500	145,730	29,146
Small break Point Chicot, Ark.	6.0	4.0	0.0 above 1888.	3.0 above old	4,000	37,920	7,584
Sappington, Ark	10.0	8.0	5.0 above 1888.	3.0 above old	650	19,136	3,827
One mile above Luna, Ark	18.0	12.0	3.0 above 1888.	5.0 above old	2,000	58,880	11,776
Two miles above Arkansas City, Ark	8.0	7.0	4.0 above 1888.	3.0 above old	400	11,776	2,355
Chicot, Ark	10.0	8.0	5.0 above 1888.	3.0 above old	250	7,365	1,473
Ferguson's (2 miles above Chicot)	12.0	10.0	5.0 above 1888.	3.0 above old	350	10,300	2,061
Boggy Bayou (opposite Fork, Ark	57.0	25.0	5.0 above 1888.	3.0 above old	300	30,000	6,000
One mile below Columbia, Ark	10.0	9.0	3.0 above 1888.	6.0 above old	650	19,136	3,827
Brookfield (opposite Fork), Ark	12.0	8.0	5.0 above 1888.	3.0 above old	700	20,608	4,121
Raleigh, La	12.0	10.0	5.0 above 1888.	3.0 above old	6,000	176,640	35,328
Total						1,313,580	262,704

NOTE.—Quantities for Mississippi obtained from chief of engineer Levee Board, and provide for new levees on permanent location as proposed to be built. For Arkansas and Louisiana the estimate is made for loops or for closing the gaps on the old line.

DISCHARGE.

The maximum river discharge was measured at Wilson's Point, La., on July 3, 4, and 5, 1889, by Assistant Engineer Tollinger.

In 1890, from January 24 to May 7, a party was engaged at Wilson's Point, La., measuring the river discharge, under the direction of F. P. Spalding, surveyor, and

also the Skipwith's crevasse, after it took place; sixty-eight complete river discharges and ten of the Skipwith crevasse were obtained.

At Arkansas City another gauging party was stationed during the time of highest water under the direction of Assistant Engineer J. J. Hoopes. Fourteen complete river discharges were obtained between March 14 and April 15 and a number of measurements of the different crevasses.

The water flowing into Lake Chicot through the Point Chicot breaks and Columbia and Luna crevasses was measured by Inspector A. F. Kilpatrick. The crevasse at Raleigh was measured on April 12 by Assistant Engineer Goodrich.

The results of these measurements are given in the reports of the chiefs of parties submitted herewith.

The observed discharge, gauge, mean velocity curves, and a discharge curve found by adding the crevasse measurement to the observed discharge, to show the volume that would have passed both Arkansas City and Wilson's Point had the levees remained intact.

Plates 3 and 4 are submitted as part of this report.

ARKANSAS CITY DISCHARGE.

The measurements of the flow passing between Arkansas City and the higher ground on the west at station Trippe, on the Little Rock, Mississippi River and Texas Railroad, was obtained as a check on the crevasse measurements on the right bank, which are all over, and within a few miles of the discharge section at Arkansas City.

By comparison with the crevasse measurements, it appears that part of the river discharge from the Arkansas River, when at its flood, flows around the end of Opossum Fork levee beyond Amos Bayou, and passes down through the low ground between Arkansas City and Trippe; the excess of this measured flow over what poured through the crevasses varied from 29,000 to 41,000 cubic feet.

A comparison of these measurements is given below:

[In thousands of cubic feet.]

Date.	Measurement crevasses R. B. above Arkansas City.	Measurement volume between Arkansas City and Trippe.	Difference.	Date.	Measurement crevasses R. B. above Arkansas City.	Measurement volume between Arkansas City and Trippe.	Difference.
Apr. 8	111	140	29	Apr. 12	110	145	35
9	120	146	26	13	106	143	37
10	117	148	31	14	104	142	48
11	114	146	32	15	99	140	41

The measurement of the crevasses on both sides of the river above the discharge section, increased by the additional water flowing between Arkansas City and Trippe, as shown above, has been added to the river discharge, to obtain the volume of water that would have passed Arkansas City, had the levees been of sufficient height to restrain the flood and no crevasses occurred.

An addition of 30,000 cubic feet has also been made to the observations prior to April 8, as the river was as high then as when the Arkansas City to Trippe gaugings were obtained, to account for the flow around the end of Opossum Fork levee.

Besides the river and crevasse discharges there have been plotted the hydrograph at Arkansas City, the difference in slope between Rosedale, 40 miles above, and Greenville, 40½ miles below, compared with Arkansas City (Plate 3).

The volume of water passing through the crevasses was obtained graphically, by plotting the observed discharges on the days they were measured, and reading off from the diagram the discharge for the particular day when the river discharge was taken.

The unusually large discharge on April 19 was evidently due to the crevasse at Offutt's, 7 miles below Arkansas City, which occurred at 4 p. m. on the 18th, and the Luna break, 28.5 miles below, that took place at 6 a. m. the same day; these breaks had the effect of causing a fall at Arkansas City while the river was at the same time rapidly rising above, causing a steepening of the slope immediately above, and also below the discharge section. This is shown by a sudden increase of slope of 0.4 feet between Arkansas City and Greenville, and 0.1 foot between Arkansas City and Rosedale.

The second large discharge, April 2, was due to the Huntington crevasse, on the left bank, ¼ mile, and the Mound break, 3 miles above. Both of these occurred March

28, and on April 2 were discharging nearly their maximum, the sudden depletion from the main river causing an increased slope above the discharge section.

The falling off of the main river discharge April 2–11 was due to the large crevasse in the levee on the upper side of Catfish Point, 16 miles above. This break occurred April 4 and widened very rapidly.

The sudden depletion from the main channel at this point necessarily caused a flattening of the slope between here and the discharge section, which, combined with the discharge of the other crevasses, required an interval of some days for the former conditions of slope to re-adjust themselves.

The large discharge on April 13 was due to the rectification of conditions previously existing before the large crevasse on the upper side of Catfish Point took place, aided by the return flow on the lower side of Catfish Point Peninsula, 7 miles above Arkansas City, of over 110,000 cubic feet per second.

The result of these observations indicate that the maximum river discharge (including the Sappington break) that the levees at their present height, under same condition of slope, would be expected to pass at this point is about 1,300,000 cubic feet per second.

The maximum discharge found by including all crevasse measurements was 1,721,000 cubic feet, leaving 421,000 cubic feet, or one-third the entire river discharges to be provided for by additional heights of levees.

A comparison of the observed river discharges at Arkansas City and Wilson's Point is given below. The crevasses between the two discharge sections have been taken into account, and the observation at the upper station compared with that taken the day following at the lower station, when a discharge was measured on that day.

[In thousands of cubic feet per second.]

Wilson's Point.				Arkansas City.		
Date.	River district.	Crevasses measurement.	Total.	Date.	River district.	Difference.
Mar. 15	1,221	7	1,228	Mar. 14	1,186	+ 42
20	1,166	40	1,206	19	1,418	—212
25	1,254	38	1,292	25	1,220	+ 72
28	1,216	54	1,270	26	1,228	+ 42
28	1,216	54	1,270	28	1,223	+ 47
31	1,199	99	1,298	30	1,250	+ 48
31	1,199	99	1,298	31	1,272	+ 26
Apr. 3	1,210	120	1,330	Apr. 2	1,339	— 9
5	1,144	133	1,277	4	1,221	+ 56
8	1,135	120	1,255	7	1,187	+ 68
10	1,118	119	1,237	9	1,220	+ 17
12	1,152	101	1,253	11	1,199	+ 54
14	1,094	92	1,186	13	1,335	—149
15	1,112	99	1,211	15	1,283	— 72

The increased discharge at Wilson's Point over that at Arkansas City is due to the Raleigh Crevasse, 34 miles below, which took place on March 15, and in a few days widened to 3,000 feet in width, and the Skipwith break, one-half mile above the discharge section, which occurred March 26; the effect of the former was to increase the slope below the discharge section, and of the latter, by the sudden depletion, temporarily to increase the slope above.

During the time covered by the Arkansas City observations the effects of the crevasses constantly occurring in the vicinity had also a tendency to decrease the river discharge at that station, except on the dates before referred to, as explained above.

WILSON'S POINT DISCHARGE.

The river discharge, and discharge through crevasses between Wilson's Point and Arkansas City, hydrograph at Wilson's Point, difference of slope between Wilson's Point and Greenville, 52½ miles above, and Duvall's, 38 miles below, compared with Wilson's Point, have been plotted. (Plate 4.)

The maximum river discharge found at Wilson's Point, 1,290,000 cubic feet per second, was on March 11, while the levees were practically intact, as no breaks had then occurred that would affect the discharge. On March 11 the river was 0.5 foot

below the highest stage reached four days afterwards, and 2.6 feet above any previously recorded high water. At the time the maximum river discharges were obtained the water was within a few inches of the tops of the levees, which in many places had been raised temporarily with filled sacks from 1 to 3 feet.

Gauge-readings of the permanent gauges and of temporary gauges kept by the levee board are given below.

HIGH-WATER MARKS.

A complete set of high-water marks have been made on trees or other permanent objects at distance of a mile or less apart, for the purpose of determining the high-water slope and as a reference for future heights of levees. These have been marked on both sides of the river through the entire length of the district.

In Louisiana the flood heights were marked under the direction of the fifth district levee board; in Mississippi, from the upper end of the district to Brunswick, by the Mississippi levee board; below Brunswick to Warrenton, and in Arkansas, the high-water marks were made by our own forces.

These are now being connected with permanent benches as rapidly as possible.

Profiles of the levees on both sides of the river, showing the relation between maximum flood heights and heights of levees, are submitted herewith. (Plates 5 and 6.)

The information as to the Mississippi levees, shown on the profile, was furnished by the Chief Engineer, who states:

"The grades of our levees in 1880 were taken from a line of levels run in 1882, previous to the repairs of the breaks of that year, with corrections for construction between 1880 and 1882, and the grades of 1890 from recent observations. Grades are referred to Memphis datum, and also to the high water of 1882, so far as known. The high-water marks of that year, however, were taken without much precision, and at very irregular, and sometimes long intervals, and are frequently involved in much obscurity. It will be remembered that our grades are only referred to 1882 in those parts of the upper end of our district where it was the highest water; in other parts, even of the upper end, 1886 was higher than 1882, and was hence adopted as the standard. Below Mound Landing, 1880 was taken as the standard, because it was confined between levees and without crevasses; 1888 differed from 1882 by very diverse figures, being at some portions of the confined reach equal to 1882, and at others below it."

The crevasses in 1890 all occurred in State levees, and in 1880 the line was complete; no crevasses took place that year.

The data for the Arkansas levees have been obtained from previous surveys made by the United States, and from surveys and examinations made the present season.

None of the crevasses occurred in levees built by the United States except the Columbia break; this was caused by the water overtopping the levee. The Opossum Fork Levee, where it crosses Boggy Bayou, was maliciously cut.

All the levees where breaks took place have been added to and strengthened by the United States at different times, but none of them were originally constructed by the Government.

The length of the line from the end of Opossum Fork Levee to the State line is 90 miles.

The gaps and breaks in this line in 1880 were from—

	Feet.
Amos Bayou to Arkansas City	17,200
Arkansas City to Linwood	20,840
Linwood to State line	56,610
	94,650

Or 17.9 miles.

In Louisiana the elevations of the high water of 1890, height of present levee, and natural surface at distance of about 5 miles apart, are shown on the profile.

This is all the reliable information at present available.

The Raleigh Crevasse occurred in a State levee which had been recently constructed.

Gauge-readings of high water of 1890, *third district, improvement Mississippi River, from February* 1 *to May* 10, 1890.

Date.	Arkansas City, Ark.	Greenville, Miss.	Lake Providence, La.	Vicksburg, Miss.	Date.	Arkansas City, Ark.	Greenville, Miss.	Lake Providence, La.	Vicksburg, Miss.
	Feet.	*Feet.*	*Feet.*	*Feet.*		*Feet.*	*Feet.*	*Feet.*	*Feet.*
Feb. 1	45.10	39.70	36.50	42.00	Mar. 23	48.80	43.17	40.20	47.00
2	45.80	39.95	36.82	42.40	24	48.90	43.23	40.22	46.90
3	45.40	40.20	37.15	42.80	25	49.00	43.29	40.25	46.90
4	45.50	40.40	37.40	43.00	26	49.20	43.36	40.10	46.90
5	45.60	40.60	37.57	43.30	27	49.30	43.41	40.00	46.80
6	45.80	40.80	37.80	43.60	28	49.00	43.25	39.90	46.70
7	46.00	41.10	38.22	43.90	29	48.80	42.95	39.75	46.55
8	46.10	41.20	38.30	44.20	30	48.60	42.85	39.60	46.50
9	46.10	41.25	38.43	44.40	31	48.50	42.83	39.60	46.40
10	46.10	41.20	38.52	44.60	Apr. 1	48.50	42.75	39.60	46.45
11	46.00	41.15	38.57	44.70	2	48.40	42.68	39.45	46.45
12	45.90	41.05	38.60	44.80	3	48.40	42.75	39.57	46.60
13	45.90	41.05	38.70	44.90	4	48.00	42.48	39.40	46.70
14	45.90	41.05	38.70	45.00	5	47.80	42.24	39.30	46.80
15	45.90	41.05	38.70	45.10	6	47.80	42.18	39.30	46.90
16	45.90	41.05	38.73	45.20	7	47.80	42.15	39.30	47.10
17	45.90	41.05	38.77	45.20	8	47.80	42.15	39.30	47.25
18	45.90	41.10	38.85	45.25	9	47.80	42.15	39.30	47.40
19	46.00	41.20	38.93	45.35	10	47.80	42.10	39.30	47.55
20	46.10	41.30	39.00	45.45	11	47.70	42.10	39.30	47.70
21	46.30	41.40	39.13	45.50	12	47.70	42.10	39.30	47.85
22	46.40	41.55	39.23	45.60	13	47.60	42.07	39.35	47.95
23	46.40	41.55	39.35	45.70	14	47.60	42.00	39.30	48.10
24	46.40	41.55	39.42	45.80	15	47.50	41.95	39.25	48.20
25	46.45	41.55	39.47	45.90	16	47.50	41.93	39.30	48.30
26	46.40	41.55	39.50	46.05	17	47.50	41.90	39.30	48.50
27	46.30	41.55	39.57	46.13	18	47.50	41.85	39.25	48.55
28	46.20	41.45	39.50	46.25	19	47.40	41.82	39.27	48.60
Mar. 1	46.20	41.35	39.40	46.30	20	47.40	41.82	39.32	48.70
2	46.30	41.37	39.40	46.20	21	47.40	41.82	39.35	48.70
3	46.30	41.43	39.45	46.30	22	47.40	41.87	39.33	48.80
4	46.50	41.55	39.54	46.35	23	47.40	41.84	39.30	48.95
5	46.70	41.75	39.64	46.40	24	47.30	41.82	39.40	49.05
6	46.90	41.85	39.82	46.45	25	47.00	41.50	39.27	49.10
7	47.20	42.20	40.00	46.60	26	46.70	41.30	39.05	49.10
8	47.30	42.40	40.19	46.70	27	46.40	41.00	38.90	49.05
9	47.50	42.51	40.34	46.85	28	46.10	40.68	38.70	49.00
10	47.40	42.51	40.45	46.95	29	45.90	40.45	38.52	48.85
11	47.50	42.60	40.50	47.10	30	45.70	40.30	38.40	48.70
12	47.80	42.85	40.75	47.30	May 1	45.60	40.20	38.25	48.50
13	47.90	43.00	40.90	47.75	2	45.60	40.10	38.15	48.35
14	48.00	43.03	40.92	47.80	3	45.60	40.15	38.15	48.25
15	48.20	43.18	41.05	47.95	4	45.50	40.00	38.05	48.25
16	48.40	43.35	40.83	47.70	5	45.40	40.00	38.00	48.10
17	48.60	43.45	40.67	46.65	6	45.30	39.85	37.87	48.00
18	48.70	43.40	40.55	47.50	7	45.10	39.70	37.85	47.80
19	48.70	43.10	40.40	47.40	8	44.90	39.55	37.70	47.60
20	48.70	43.10	40.25	47.20	9	44.70	39.35	37.63	47.40
21	48.80	43.15	40.23	47.10	10	44.50	39.15	37.45	47.30
22	48.80	43.20	40.27	47.05					

[Memphis datum.]

Date.	Rosedale, Miss.	Duvalls, Miss.	Date.	Rosedale, Miss.	Duvalls, Miss.	Date.	Rosedale, Miss.	Duvalls, Miss.
	Feet.	*Feet.*		*Feet.*	*Feet.*		*Feet.*	*Feet.*
Mar. 5	.....	108.90	Mar. 21	163.93	108.90	Apr. 6	.....	108.20
6	161.68	109.00	22	163.98	108.90	7	.....	108.35
7	161.88	109.00	23	164.03	108.90	8	.....	108.35
8	162.08	109.25	24	164.18	108.85	9	.....	108.35
9	162.18	109.45	25	164.38	108.85	10	.....	108.35
10	162.18	109.60	26	164.68	108.75	11	.....	108.35
11	162.28	109.70	27	164.78	108.75	12	.....	108.40
12	162.48	109.70	28	164.88	108.55	14	.....	108.45
13	162.58	109.95	29	164.93	108.45	15	.....	108.40
14	162.78	110.10	30	164.98	108.30	17	.....	108.50
15	162.98	110.15	31	.....	108.25	22	.....	108.50
16	163.18	109.80	Apr. 1	.....	108.30	24	.....	108.60
17	163.38	109.50	2	.....	108.25	28	.....	108.30
18	163.58	109.35	3	.....	108.20	29	.....	108.15
19	163.68	109.20	4	.....	108.20	30	.....	108.00
20	163.78	109.00	5	.....	108.20			

REPORT OF MR. E. C. TOLLINGER, ASSISTANT ENGINEER, ON THE HIGH-WATER PROTECTION OF LEVEES AND THE FLOOD OF 1890.

The following report of the care and protection of the levees of the Tensas Basin Front, Arkansas, and of the overflowed portions of Desha and Chicot counties, is respectfully submitted:

These levees were built by the State of Louisiana, its district boards, levee boards of Arkansas, railroad corporations, the United States Government, and private subscriptions. They have been built from time to time, without any established grade or proper care given to their foundations, selection of material, or cross-section. These have been enlarged and raised on old railroad embankments and private levees, without a thorough examination of the old structures, and the result is a poorly-constructed embankment to serve the purpose of levees. These levees have not been built on any well-considered plan, and no one seems to be responsible either for their size or location.

There was a more active interest taken in 1887-'88-'89, and considerable progress was made in building new and raising and enlarging the old.

During this period the grade was raised from Amos Bayou to Lucca Landing 3 feet, and from Lucca Landing to Arkansas City 2.5 feet above high water of 1889; from Arkansas City to Linwood 5 feet, and Linwood to Louisiana State line 3 and 4 feet above high water of 1888. (See tabulated statement herewith.)

The levees as raised were designed both as to height and dimensions of cross-section to pass only the highest water on the Arkansas City gauge previously recorded, as shown by the high water of 1882. Had this height not been exceeded, the levees, without doubt, would have remained secure.

From Amos Bayou to Louisiana State line a large force was employed raising and strengthening weak places.

Through the high-water period, not 1 mile of the 90 miles of levee along the Arkansas front but required constant watching, day and night.

These levees in general are well protected from wave-wash.

Fifty miles required little more than day and night force to prevent stock from causing sloughs. Forty miles required a large force of laborers, day and night, to keep the levee intact.

This was notably so from Lucca Landing to Arkansas City, 9 miles, Arkansas City to Fulton Lake, 2 miles, and from Linwood to Vaucluse, 16 miles.

METHODS EMPLOYED.

First. To prevent overflow: Sacks of earth laid longitudinally on top of levee in tiers, one above the other, so as to break joints, or a wall of plank backed with earth.

Second. To prevent wave-wash: Sacks filled with earth and laid along at edge of water on side of levee, or other material when sacks could not be had.

Third. To prevent and repair sloughs: A shingling of levee with sacks of earth laid on a thick layer of brush, so arranged as to allow a free escape of the water, and supported at base of levee by a strong row of firmly driven and well-braced stakes.

Fourth. To lessen or stop seepage due to various causes: Loose earth dumped on the river side, or canvas laid in place and weighted down with sacks filled with earth.

Fifth. To stop breaks from widening: Many methods were employed, depending on the nature of the soil, height of levees, volume of water, location, accessibility, material on hand, etc.

The most satisfactory plan being a dike constructed of piles, brush, and sacks filled with earth. The piles are driven 10 or 15 feet in the ground, from 6 to 8 feet apart. A strong screen mat, made of willows or brush and trees, cut and put in place and safely secured with wire cables, is then sunk against the piling with filled sacks. This enables the construction of a dike of filled sacks to be made on the lower side of the piling. The dike usually begins about 100 feet from end of levees, and makes an angle with same of 70°, and extends from 75 to 100 feet into the current.

OVERFLOWED AREA.

Twenty days in advance of the maximum height reached at Arkansas City it was evident that breaks in the levees would occur. The timely notice given to the people living behind the levees, together with the small size of the crevasses in this section, enabled them to make provision for safety of themselves, their stock, and other property. No great suffering, loss, or destruction immediately followed the breaking of the levees.

Areas overflowed.

	Square miles.
Chicot County, overflowed	577
Chicot County, above overflow	133
Desha County, overflowed	546
Desha County, above overflow	100

Between Dumas and Varner (or 30 to 40 miles from Arkansas City), the overflow was 5 feet above the track of the Little Rock, Mississippi River and Texas Railroad.

The opinion prevailed that this water was discharged into Bayou Bartholomew, and thence south; a special examination was made which proved conclusively that there had not been any such discharge.

HIGH-WATER MARKS.

A number of high-water marks were made on trees at the time of the highest water, by driving in a 6-inch boat-spike marked H. W. 1890. These were placed about one-half mile apart, but this distance was reduced where cross levees and change of slope required. The elevation of these marks (about two hundred in number) have been determined and compared at important points with the high-water marks of 1882 and 1888. This table shows that the height of the flood of 1890, above that of 1888, was much greater above than below Arkansas City. The peculiar topography of the country between the Little Rock, Mississippi River and Texas Railroad, and the Arkansas River, and the construction of the railroad embankment itself, is probably the cause of this anomaly.

It is evident that the levees in this section will need an additional topping of 3 feet when compared with the increase of height at the lower end of the State, that may be required to pass future floods.

In order to give full protection to the country lying south of the Arkansas River, it will be necessary to extend the levee system from the mouth of Cypress Creek, across Caulk's Point, some distance up the Arkansas River.

Statement comparing high-water marks of 1882, 1888, *and* 1890, *and giving cross-sections of levees.*

[Elevations are from Memphis datum.]

Location.	High water, 1882.	High water, 1888.	High water, 1890.	Difference, 1888 and 1890.	Height of levee.	Width of crown.	Base of levee.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Amos Bayou	.....	155.76	161.10	5.34	161.4	4	30
Boggy Bayou	.....	155.00	160.84	5.84	161.5	4	96
Opossum Fork	.....	154.07	159.56	5.49	159.6	4	112
Lucca Landing	.....	152.05	157.31	5.26	158.9	4	64
Chicot	.....	150.28	155.61	5.33	154.7	4	52
Arkansas City	150.34	148.42	152.62	4.20	151.1	16	34
Gaines' Landing	.....	145.29	148.77	3.48	148.7	8	68
Linwood Landing	141.96	140.50	144.04	3.54	144.8	4	46
Luna Landing	.....	140.40	143.15	2.75	143.0	4	38
Vaucluse	.....	133.90	136.40	2.50	139.0	8	68
Sunnyside	.....	132.30	135.18	2.88	136.2	6	29
Lakeport	131.39	131.40	134.05	2.65	134.5	6	65
Grand Lake	.....	126.51	129.02	2.51	130.2	6	45
Hilliards	.....	125.61	128.31	2.70	128.4	6	27
Sterling	.....	124.28	126.55	2.27	127.3	6	26
Louisiana State line	.....	.....	125.55	.....	127.5	6	.....

Statement of amount expended for protection and repairs to levees of Tensas Basin Front in Arkansas, 1890.

Locality.	Pay-roll.	Subsistence.	Total.
Amos Bayou to Linwood	$13,906.46	$2,484.87	$16,391.33
Linwood to Vaucluse	8,416.89	1,103.56	9,520.45
Vaucluse to Lakeport	766.76	77.44	844.20
Lakeport to Louisiana State line	1,667.34	.....	1,667.34
One-third expenses steamer Etheridge, March and April	.....	.....	900.15
Total	24,757.45	3,665.87	30,023.47

The expense of charter of steamer *R. A. Speed* is not included in the above.
The cost of material used is also left out.

During the flood the strain on everybody who was engaged in an effort to hold the levees was excessive. Work was continued night and day.

At Arkansas City, 140,000 sacks were brought in on the railroad; most of these were used in front of the town, and the rest were loaded on barges and used north of Chicot.

As would be expected in an emergency of this kind, the work was an enormous cost, and the money would have been much better applied in raising and strengthening the levees before the high water.

The interval was too short to make the levees secure against overflow, even if unlimited funds had been at our disposal.

REPORT OF MR. HENRY GOODRICH, ASSISTANT ENGINEER, ON THE HIGH-WATER PROTECTION OF LEVEES AND THE FLOOD OF 1890.

In compliance with orders of March 23 and 28, directing me to take charge of the steamer *Osceola* and of the Government forces thereafter to be engaged in assisting the Fifth Louisiana Levee Board in protecting its line of levees from the Arkansas State line to Bedford's (opposite Warrenton), I now report completion of that service in the manner briefly stated below:

The first aid rendered by the *Osceola* was in transporting overflowed people and live-stock from the vicinity of Raleigh Break to nearest dry ground, and in delivering forces and material (lumber, sacks, and bagging) for protecting levees to the places endangered.

In co-operation with the president and engineer of the Levee Board, who generally accompanied me, plans of work were adopted and organized forces started where most needed along the line, as given below. To enable me to judge of the necessity and kind of work to be done, to organize forces, and to pay for labor performed, the *Osceola* was kept constantly in use, visiting all points of danger and rendering the needed aid. On two occasions, by your special permission obtained, at the time of highest flood and greatest danger to the line below Bedford's, the *Osceola* went as far down as St. Joseph and Concordia Break to deliver a pile-driver for use in preventing the widening of gap. In this connection it may be mentioned that a fleet of several willow barges, mattress barge, rock barge, stock barge, coal barge, and pile-driver, were kept in readiness at Alsatia for use in emergency.

At each end of Raleigh Break a willow mattress was made to protect them from widening; but constant care needed to be given in supplementing them with willow bundles, weighted with sacks of earth, between each end and its mat.

The swift lateral return-current in the overflow against the levee threatened to wash it seriously, and had to be deflected by spur dikes of timber and planks. The mattresses also had to be similarly protected on the upper side from the erosion of the strong current down along the levee, setting in toward the break.

A brief sketch of the condition of the line of levees at the beginning of the present high water, and mention of the recent work accomplished by the Louisiana State Boards, are here added as explanatory of the situation. Prior to Government aid this season they had expended a very large sum in systematic raising and strengthening the line planned for the entire fifth district, accomplished in scattered portions only, and interrupted by the early and long continued high water.

But for this timely preparatory work of enlargement to better grade and section, as State funds permitted, the struggle for maintenance of line against this unusual flood-wave would have been, without doubt, far more perilous even than it was.

From Filcher's Point to Wilson's the river raised 3¼ feet higher than observed at any previous year, and left the levee a very small margin of about a foot above water.

At Lake Providence the increased height was 2.6 feet higher than in 1882.

Two large new levees, Raleigh and Longwood, were in process of construction for the State, to replace old front lines which were about to cave off.

Protection loops at each of these places had to be built as the caving continued, to restrain the river and to allow time for finishing the main line, and were themselves held with great difficulty and cost till that object seemed accomplished.

At Raleigh the main line was closed only a day before the loop caved off (February 30, 1890).

A sudden rush of water filled up against the new embankment an average depth of 9 feet, causing sudden and unequal saturation and irregular settling, all the greater on account of mixed material, silt and sand, heaped up by wheelbarrows about 12½ feet high.

The portion first built, the north end, had appeared solid and safe, and least of all was suspected of breaking.

A general settling of material had taken place, but to outward appearance, at the

place which broke, the shape and proportions were better preserved than elsewhere, and had called for no extra work.

Without premonition of special weakness, the land slide slipped with sudden softening from saturation. This induced a rush of semi-fluid material, by hydrostatic pressure, and the river followed.

In a few days the break had widened to 4,500 feet, and since then has been held in check by end-protection.

The break occurred at 5 p. m. March 15; gauging was made April 12. The actual stage of river at either date could not be then referred to any standard datum on account of the inaccessibility of benches, but will be reported later.

A single discharge observation by a score of located soundings and surface velocities, as given in separate report, gave an average depth of 13.3 feet, mean reduced velocity 2.7 feet per second, width 4,600 feet, and consequent discharge of 166,000 cubic feet per second. The location of the crevasse was within the first or upper mile of the new levee.

The average net dimensions of levees in north Louisiana are in height at present 10 feet (from 7 to 13), with crown 6 feet, and slopes 3 and 2 to 1, the longer slope on the river side.

New lines have higher grade and larger sections, crown 8 feet, slopes 3 and 3 to 1, when sufficient funds for construction are available.

An additional rise of 1 foot this season would have hopelessly overtopped miles of levee more than could have been maintained successfully under all the disadvantages of the season.

As a fact, the actual height of raising the old grade, after the high water came, was in many portions nearly 2 feet, with very little margin above water.

The places at which Government aid was given, under my direction, besides the Raleigh break, were generally:

First. High, steep, narrow levees, thoroughly saturated, and about to slide or slough.

Second. Narrow-topped levees badly wave-washing, and about to be cut through.

Third. Low levees about to be overtopped.

Fourth. Leaking levees, perforated and endangered by crayfish holes, trickling, muddy water and sand, from interior cutting.

Fifth. Exposed levees, eroded by strong impinging currents.

Sixth. Combination of these conditions.

The methods of adding strength to weak and insufficient levees are as various as the particulars of individual weakness, and suggest themselves under special conditions.

A slide or slough can generally be successfully checked by placing willow brush upon the slope, limbs upward, weighted near the base with sacks of earth and by a plank, well braced.

The willow twigs serve to drain off the saturation and at the same time to support the material.

Worse cases need enlargement of section under water, to restrain percolation and seepage, a most efficient and successful remedy, especially in places remote from the action of strong currents.

Still worse cases require not only the foregoing treatment, but an additional land-side section built up from a secure retaining-wall of plank, of dry earth, or, still better, with sacks of earth.

Wave-wash can be checked by a plank-wall, or sheet-piling, or, still better, with sacks of earth which readily remain where placed. If the washing has just begun on a long stretch, common jute bagging, unrolled and well staked down, will arrest the force and damage to a considerable extent.

A sand boil, or crayfish-hole, discharging sand and mud, can often be smothered by weighting the corners of a square of bagging over it so as to strain off the water and retain the material, to obstruct the flow.

Often a weighted barrel or large cylinder placed over it has been used to catch the flow till it stopped by equalized pressure.

Exposed angles of levees are best protected by spur-dikes of plank, in connection with willow bundles, weighted with sacks of earth, and secured by ropes or wire to the solid embankment.

Draining from the base the surface accumulation will greatly aid in maintaining a saturated embankment.

The tramping of cattle, as in grazing on the levee-slope, during the season of high water invariably causes trouble, and often disastrous consequences.

The ends of crevasses can best be protected by deflecting the currents from them by a row of thickly-driven piles as a spur-dike, projecting from each end at a gentle angle into the current, and sinking bundles of weighted willows against the piling to obstruct flow.

Crevasses commonly occur from some of the causes of weakness above enumerated,

intensified by faulty construction as to preparation of base, selection of clean material, tamping of mock ditch, etc.

With sufficient funds, the dimensions of sections, in every respect, should be increased by a liberal factor of safety, and a few new specifications added to those now commonly adopted, looking to the better construction and location and preservation of levees by systematic, annual, and studious care.

An unhesitating preference should be given to scraper work over wheelbarrow, where location permits, as it results in a compact embankment, with better chances of withstanding saturation and unequal shrinking, even though subject to superficial criticism of washing more from severe rainfall, a loss that is far more than counterbalanced by compactness.

In directing the work under my charge, as Government aid towards restraining the river within its training walls, I have undertaken only such work as I deemed necessary, and have limited it to its minimum of labor and cost.

LABOR STATEMENT.

Location and cost of work by United States forces, in protection of north Louisiana levees, from Ashton to Bedford's, March, April, and May, 1890.

Locality.	Labor.	Total pay-rolls.	Remarks.
	Days.		
Millikin's Bend	1,195	$1,837.70	Stopping sloughs, wave-wash, topping.
Omega	508	664.65	Stopping sloughs, wave-wash, topping.
Raleigh Break	1,448	1,985.73	M ttressing and revetting ends.
Buckhorn	609	677.35	Stopping sloughs.
Bedford's	333	469.36	Do.
Bunch's Bend	40	47.45	Stopping erosion of current.
Longwood	63	73.64	Stopping wave-wash.
Blue Ridge	273	390.86	Stopping sloughs.
Pecan Grove	110	155.63	Raising top and strengthening.
Henderson	64	72.70	Stopping erosion and wave-wash.
Survey	23	87.90	Making overflow reconnaissance.
Osceola pay-rolls	1,123	2,416.46	Salaries of officers and crew on steamer *Osceola* and on overflow.
Subsistence, supplies, and traveling expenses.		291.27	Reconnaissance.
Total	5,789	9,170.70	Not including cost of fuel for *Osceola*.

Information through reconnaissance parties, relative to the extent of the flooded territory, traced with care, has been obtained, and the elevations of high water marked and described, and will soon be evaluated in reference to Memphis datum plane.

This information will be the subject of a separate report, and contributed to the comprehensive report and map of the entire third district, Mississippi River Commission, now in progress.

The aid rendered in my special subdistrict has been timely, necessary, economic, and successful.

Leaving out Raleigh break (which occurred prior to the national aid), there has been no mishap on the line on the west bank from Ashton to Bedford's, though numerous threatening dangers from time to time have been met and remedied.

The following report, submitted to the committee on resolutions of the Mississippi River improvement and levee convention, which met at Vicksburg, Miss., on April 30, 1890, is quoted as bearing directly upon the history of the flood of 1890:

REPORT OF ENGINEERS.

VICKSBURG, MISS., *April* 30, 1890.

To the Committee on Resolutions of the Mississippi River Improvement and Levee Convention:

Your committee, to whom was assigned the duty of preparing a statement on the subject of levees, beg leave to submit the following:

The testimony of all engineers familiar with the subject is that there is no engineering difficulty in the way of restraining the floods of the Mississippi River through the agency of levees, and that this is the only agency through which that object can be accomplished. The levees, as they existed at the beginning of the recent flood,

were admittedly too weak generally, in heighth and width, to stand an extraordinary high water, as was recognized and affirmed by all levee engineers.

The fundamental defect in the present system of levee building is that they have not been designed and constructed on engineering principles in the most thorough manner, with the sole view to certain efficiency, as is the case in all other classes of engineering work; but it has always been a mere question of doing the best that could be done with an insufficient amount of money.

The great desideratum has been to pile up as much dirt as possible in the cheapest possible way, so as to cover the greatest extent of territory with the highest bank of earth attainable with the means at hand. This consideration has precluded such treatment of the foundations as the character and service of the structures demanded, to which deficiency is attributed much of their failure to successfully resist the extraordinary pressure of this flood at various points. The disasters from the recent flood have been exaggerated and magnified beyond their true proportions by the sensational treatment which the subject has received, and which has tended to shake confidence in the efficiency of the levee system.

In confirmation of this attention is invited to the following facts: In 1882 the total number of crevasses in the levees was 284, aggregating 56.09 miles in width; in 1883 the number of crevasses was 224, with an aggregate width of 34.1 miles; in 1884 the crevasses numbered 204, aggregating 10.64 miles in width.

The result of the crevasses enumerated during these three years was a general overflow of the Mississippi Delta. In the present flood, the dangers of which are nearly passed, the crevasses which have occurred numbered twenty-three, aggregating about 4¼ miles in width, in a total length of 1,100 miles of levees, or less than one-half of 1 per cent. of the total line of levees, notwithstanding that the present flood has exceeded those of the three years cited in the height attained at Memphis and all points below, and has not been exceeded in duration. This excess of height was, at Memphis, 0.5 foot; at Helena, 0.6 foot; at Sunflower Landing, 1.2 feet; at Arkansas City, 2.3 feet; at Greenville, 1.7 feet; at Providence, 3.1 feet; at Vicksburg, 0.1 foot; at Natchez, 0.8 foot, and at New Orleans, 0.5 foot.

The general result has been a large measure of protection afforded by the levees this year, notwithstanding the extraordinary character of the flood, which has never been enjoyed during previous high waters of considerable magnitude.

For example, in the Yazoo Basin between 80 and 85 per cent. of its area is protected from overflow, there being only one crevasse of 280 feet in width, affecting a very small area, in 180 miles of levee, extending from the upper extremity southward. There were other crevasses on this front below this locality. On the Tensas front are two reaches of continuous levee, being respectively 81 and 125 miles in length. The right bank below Red River has 180 miles of continuous unbroken levee, and the left bank has 200 miles with only one break. Of the territory dependent upon the last-named levees, 75 per cent. has been protected. The percentages of areas protected as above noted embrace all classes of lands subject to overflow; as the lands sought for cultivation are the more elevated portions, the percentage of their area protected is much greater.

From our knowledge of this subject we now feel justified in declaring that very great progress has been made during the past five years in the construction of a complete levee system by the joint efforts of the General Government and the riparian States; and also that the experience of the present flood has strongly added to our conviction that such a system presents the only solution of the protection of the alluvial valley from inundation in connection with the general improvement of the river. We unhesitatingly express our condemnation of all theories for the regulation of the Mississippi River and controlling its floods by the agency of "outlets." It is our conviction that such a system would prove destructive to all the interests which are sought to be conserved and improved in connection with the treatment of the Mississippi River. We also state with thorough conviction and emphasis that the belief entertained by some that the effect of long confinement of the Mississippi River by levees will be to produce a permanent elevation of the river bed is a fallacious one, which is refuted by experience and contrary to all observation. We are familiar with all surveys that have been made of the Mississippi and with its present navigation, and declare that there is no evidence from either of these sources or elsewhere of progressive elevation of the bed of the Mississippi River from levees or other cause, except where caused by and immediately below outlets.

We submit the following information relating to expenditures upon the levees from the following sources:

By the United States Government, through the Mississippi River Commission since 1882	$3,018,601.50
The Mississippi levee boards since 1882	3,098,745.74
State and levee districts of Louisiana since 1866	15,255,327.13
Of which since 1882 about	5,000,000.00
Arkansas	340,417.00

The above do not include expenditures which have been made by counties, corporations, and individuals in the several States. We estimate that a further expenditure of $10,000,000 by the General Government, in co-operation with the riparian States, if promptly applied, will suffice to complete a system of levees that will prove entirely effective to restrain all future floods of the Mississippi River.

J. H. WILLARD,
Captain Engineers, U. S. A.
W. YOUNG,
Captain Engineers, U. S. A.
B. M. HARROD, C. E.
S. W. FERGUSON, C. E.
HENRY B. RICHARDSON, C. E.
WM. STERLING, C. E.
T. G. DABNEY, C. E.
H. S. DOUGLAS, C. E.
ARTHUR HIDER, C. E.
H. BOLIVAR THOMPSON, C. E.
H. ST. L. COPPÉE, C. E.
JNO. SMYTHE, C. E.
HENRY GOODRICH, C. E.
JNO. EWENS, C. E.
GEO. M. HELM, C. E.
HORACE MARSHALL, C. E.

AMELIA, ARK., *May* 3, 1890.

MY DEAR SENATOR GEORGE: I fully indorse the report of the engineers to the Vicksburg convention as to the efficiency of a proper system of levees and the futility of all other proposed plans for preventing overflows. The most hopeful thing which has occurred within my knowledge of levee history is the remarkable endurance of the present weak line in the face of the late enormous flood.

Very truly, yours,

SMITH S. LEACH,
Captain of Engineers.

Hon. J. Z. GEORGE.
United States Senate.

The following extracts, taken from a late report (date April 23, 1890) of Maj. William Sterling, chief engineer of the board of Mississippi levee commissioners, are, by permission, quoted, as bearing directly upon the history of the flood of 1890:

REPORT OF CHIEF ENGINEER.

ENGINEER'S DEPARTMENT,
BOARD OF MISSISSIPPI LEVEE COMMISSIONERS,
Greenville, Miss., April 23, 1890.

* * * * * * *

This flood must unquestionably take rank among the very great ones, with 1858, 1862, 1867, 1882, and 1884. It was not, perhaps, of greater duration than the first, nor was the maximum quantity of water at any one time as great as in the last two, nor was it in any respect as formidable as 1882, but it is probable that, taken all together, it was not exceeded by any except 1882.

It proceeded mainly from the Ohio and its tributaries, aided materially by a very high stage, maintained with great constancy, in White River, and several considerable rises from the Arkansas.

There were no less than six rises in the upper Ohio, which were met by freshets from the Cumberland and Tennessee, resulting in four distinct rises at Cairo, culminating at stages of 43.7, 41.8, 48.9, and 48.8 on the gauge at that place. The intervals between these rises were so short that the corresponding falls never reached the lower part of our district, being overtaken in each instance by the succeeding swell. Consequently the strain was first felt in the extreme southern portion of our line, where a very high stage was attained while the upper division was enjoying perfect security.

At Skipwith's the river in February was 1 foot above 1882, while at Australia it was 2 feet below, and while at Helena the gauge marked 4 or 5 feet below the record of that year. This condition of things gradually changed. The third and fourth rises brought the Helena gauge to 47.7 and 47.5, respectively; 0.5 and 0.3 above 1882,

and 0.4 and 0.6 below 1886. The strain was now transferred to the upper part of the line, the lower part having been relieved in the mean time by the crevasse at Raleigh, in Louisiana.

The condition of our line at that time was as follows:

In pursuance of the plan of enlargement approved by the board, some portions of the upper end of the district had been brought to standard, that is, to a grade 3 to 3½ feet above the highest water recorded, usually 1886, sometimes 1882, a crown of 8 feet, and slopes of 3 to 1 on each side. Some other portions of the line had also been brought to this standard, namely, all the new levees constructed during 1888 and 1889, and some little enlargement work, the programme being that henceforth wherever new work or enlargement was undertaken at all, it should be brought to these dimensions.

The other portions of the line as far down as Mound Landing were built to a grade 3 feet above high water, a front slope of 3 to 1, and a crown of 8 feet, the back slope being left unenlarged for the present.

Below Mound Landing the grade heretofore adopted was 5 feet above 1888, the standard of that year. Owing to the insufficiency of our means, in order to attain this height over as large a part of our line as possible, the crown was made only 2 feet, it being intended during the coming year to increase this to 8, and the grade to 5.5 above 1888.

The reason that 1886 and 1888 were respectively adopted as the standards above and below Mound Landing was this:

It is known that a moderate flood is no criterion at all for a high one. Even at high water is not an accurate criterion for a higher one, as will be presently seen. Nevertheless, the best we can do is to select the highest attainable record as a basis, unless some other consideration intervenes. Now, 1886 was not nearly so great a flood as 1882 or 1884, but it was more closely confined, by the rebuilding of the levees in the upper district of the Mississippi and the partial rebuilding of the Arkansas line. Therefore, it attained a much greater height at Helena than in 1882, and was also considerably higher for long stretches of the upper part of our line, notably in the vicinity of Catfish Point. Moreover, the high-water line of that year had the great advantage of not being vitiated by numerous crevasses. Wherefore, it was adopted, except where it was exceeded by the mark of 1882, in which event, for greater safety, the latter was made the standard.

Below Mound Landing, however, the line of 1886 was no longer trustworthy, on account of the number of breaks in the Arkansas levees. The first year in which the water of the river was entirely confined between levees from Arkansas City to Vicksburg was 1888, and it so happened that for a considerable portion of that reach it equaled or exceeded the greatest previous record, with the exception of 1862, and the records of that year are so fragmentary and uncertain that they can only serve as a check or a warning and not as a guide. Therefore, below Mound Landing the high water of 1888 was made the standard, and the grade fixed at 5 feet above that line. At the same time, the opinion was expressed (see my report of May 14, 1889) that this grade was not safe in itself, but relied rather on the weakness of our neighbors across the river, which weakness was continually diminishing, and, as the result abundantly shows, was not to be depended on at all.

Previously to 1888 the high-water fight had always been above Mound Landing. The levees in Washington and Issaquena counties had practically given but little trouble. The almost unleveed front of Arkansas directly opposite us acted as a waste-weir, and the water could not attain more than a certain height, be the floods never so great. The quantity of the total flood discharged over this bank of course increased as we go down the river, the portion thus lost being, in 1886, we will say, at Arkansas City about 10 per cent., opposite Greenville about 20 per cent., at Ashton about 35 per cent. of the whole discharge of the river. There were no precise observations in 1886. These approximations are very rough.

The rebuilding of the Arkansas levees in 1887 put a new face upon matters, and the high water which prevailed in the lower part of our district during the very moderate flood of 1888 indicated the urgent need of greatly increased dimensions for our levees in that portion of our line. For the last two years, therefore, our main strength has been thrown on the enlargement of the levees in Washington and Issaquena counties, and they have been given all the dimensions that our means would permit.

Under the conditions mentioned above the first trouble experienced was at the lower end of the district, where portions of the levee were deficient. This was partly due to the fact that the contracts in force did not extend entirely throughout the district, partly to the unfinished state of these contracts. In the case of the enlargements the contractors were caught by the rising river before the time limited for the completion of their work. In the case of the new work, namely, the Clover Hill and Hall's Landing levees, it was partly the misfortune of the contractors in adverse weather and insufficiency of labor, and partly their fault, that their levees were not completed at the stipulated time.

As it was, no disaster happened in the case either of the new work or the enlarge-

ment of the old. Owing to the exertions of Mr. Hyner and Mr. Marshall, the former were completed in time enough and the latter were topped to a sufficient height. On the 10th of March the levee at Raleigh, La., gave way and in a few days caused a fall in the water-surface of the river varying according to situation and amounting, in the immediate vicinity, to about a foot and a half. The scene of danger was now shifted, it was thought, from the lower to the middle part of the district, the extreme upper part being yet comparatively safe. The principal cause of apprehension here was the lowness of some of the levees, which were threatened with being actually overtopped.

* * * * * * *

It was found that the work of securing the ends of the breaks where the crevasse was of very recent occurrence, the levees high, the material light, and the current strong was a very serious undertaking, and the methods formerly practiced, of direct revetment by sacks, brush, etc, of no efficacy at all. Resort was then had to a method first practiced, so far as I know, by Mr. H. M. Marshall at Grand Lake in 1888, of building spur-dikes near the broken ends and thus throwing that destructive portion of the current that runs parallel to the levee further out and beyond the ends. Mr. Marshall's dikes were made of brush and sacks. In the deep water in which we were obliged to work it was thought better to adopt the modifications practiced with great success by Mr. Atkins in Arkansas, of driving piles, or utilizing trees where they existed, and lodging brush against them, and, under cover of this protection, building walls of sacks. This method, which is susceptible of endless modifications, has been successful wherever adopted.

* * * * * * *

The manner in which these breaks occurred, so far as is known, has always been the same. They went from the bottom. In no instance were the levees overtopped by the water. All except the Huntington Levee were comparatively new works; the Offutt Levee having been built in 1879, the Skipwith and Easton levees in 1882–'83, and the Catfish Point Levee in 1886. This fact, together with the manner of the break, pretty much excludes the supposition of unsoundness or cavities within the body of the levee. Two of them, at least, were built through open fields, where there was no timber. In every case in which the break was observed the cause was evidently under the levee and not in it, the break taking place in the natural surface, on the land side of the levee. These circumstances point with a probability which is almost certainty to the conclusion that the weakness lay in a sandy stratum, either immediately beneath the levee or only a short distance below the ground. This soil is of a much looser consistency than that of the levee itself, since the latter is packed, while the former is spongy and permeated with roots, pores, and fissures. If the borrow-pits extend into this stratum, and it be consequently exposed to the enormous lateral pressure of water at a great depth, continued for weeks and months, it becomes thoroughly infiltrated with water and reduced to an almost semi-fluid condition, being thus capable of partially transmitting a hydrostatic pressure. The weight of the levee is sufficient to withstand this pressure, but it is exerted with destructive effect on the thin crust of natural soil, just inside of the levee, and bursts it up. I once saw such a break, and the above reasoning forced itself upon me with strong conviction; and the description of the breaks at Huntington and Catfish Point, from eye-witnesses, tallies precisely with my own observation. That the other breaks proceeded from the same cause can not positively be asserted. There has been some talk, since the break at Offutt's, of a hole in a drainage-ditch inside the levee, but I have not myself seen the witnesses of this, and do not know how much importance to attach to their testimony. A hole of this kind may be of great consequence, or none at all, according to circumstances. In each instance the existence of a light sandy stratum at or near the surface of the soil is notorious, and all the circumstances favor the supposition that it was the sufficient cause of all the crevasses. Another would probably have occurred at the hoop, above Major Edmond's, had it not been for Mr. Somerville's and Major Redmond's prompt and timely action, as the soil on the land side of that levee had already begun to bulge upwards. Doubtless it would have burst had it not been heavily weighted.

This element of weakness had long been known to me, but it was thought that the dimensions given to our levees, sanctioned as they were by long experience, were sufficient to overcome it. It is now evident that they were not. Even, however, if it had been known that such was the case, it would have been out of our power to avert disaster. Our levees were nowhere superfluously strong or superfluously high and whatever labor was bestowed on strengthening lines now known to have been weak must have been diverted from other points where it was almost equally necessary. Had these or other breaks not occurred at the time they did, the river must have gone much higher. We might have been overtopped, for there was much levee that lacked but little of letting the water over it. Had we, by diligent labor, escaped that danger, and topped the deficient places to a sufficient height, yet it was not in our power

to give them proportionate strength, and our disasters, bad as they are, might have been far worse.

The occasional deficiencies in grade to which allusion has been made are due to the fact that no one flood is an accurate criterion for another. When, therefore, we build our levees 3 feet higher than 1882 or 1886, or 5 feet higher than 1888, we do so with the perfect knowledge that when a much higher water comes it will not be uniformly higher all along the line. But we can not, till engineers become omniscient, tell where all the discrepancies will occur or how great they will be. At one point the water will be perhaps 2 feet higher than the standard, at another 3; thus at Skipwith's this year it was nearly 3½ feet higher than 1882 or 1888, while at most other parts of the line it was only 2½, and that, too, before any breaks had occurred. The causes of some of these discrepancies are known and have been provided against. This particular instance is a type of several that have occurred this year, and appears due to a cause not heretofore suspected, by me at least, for the reason that I have never before seen a flood high enough to bring it prominently into play, and that is the movement of large masses of water across unleveed points. Above Skipwith's the long point called Sarah's Island lies outside the levee, and the water has a free course over it. This movement, then, as far as it goes, acts like a cut-off, lowering the water-surface in the bend above the point, while it raises it in the bend below. This was strongly exemplified by the break at Connelly's on Catfish Point, which lowered the water-surface at Bolivar by about a foot. Suppose instead of a break 2,000 feet wide the levee had been entirely washed away. The depression at Bolivar would have been still greater. The situation would then have been precisely that of an unleveed point, and the water-surface in Choctaw Bend below would have been raised as a cut-off.

This cause acted also in other floods, but to a much less extent. It makes a vast difference whether water runs across a point 2 feet deep or 5 feet deep, the velocity increasing enormously in the latter case. Therefore, while in 1882 or 1888 the water-surface at Skipwith was somewhat raised from this reason, in 1890 it was raised disproportionately more. At Neblett's Landing and at the lower end of the Miller's Bend Levee the same conditions prevailed, and the same phenomenon was observed. In the one case the flow is across Indian Point and in the other across Ashbrook's Point. In each instance the levees appeared unduly low, but they were not. The water was unduly high.

February and March, and even the earlier part of April, were marked by the prevalence of unusually high winds. Here, too, the influence of the extraordinary stage of water was felt in submerging deeply lands heretofore overflowed slightly, or not at all, and exposing to wave-wash levees formerly deemed altogether exempt from that danger. This was particularly observable in the lower part of the district, where, consequently, we had prolonged and repeated fights against the winds, necessitating the use of vast quantities of sacks. Most of these fronts will hereafter have to be protected by revetments or breakwaters of some kind.

The high-water expenses have been proportionate to the magnitude of the flood, and I fear they will be found unprecedentedly great. Everything has been done that seemed practicable to prevent waste and unnecessary work, but with only limited success. Organized forces have been used to a considerable extent, and I think it will be found advisable in future great floods to make still more use of them, and, in fact, as far as possible, employ them altogether in high-water work.

It is yet far too early to present accurate estimates of the work which will be required to replace that which has been lost, still less is it possible, at this time, to calculate the increase of grade which will be necessary to bring our levees to a safe height. There will be ample data for such estimates when the high-water observations are all reported. These will be unusually full this year. The Government has out numerous parties measuring the discharge of the river at various points; among others, at Helena, Arkansas City, Wilson's Point, and Vicksburg, as well as at the several crevasses on both sides. Two very complete series of high-water marks have been taken by our own organization, one at the top of the second rise before any breaks had occurred, the other at actual high water. These marks were taken at every mile. It is hoped that it will be possible, from all these data, to fix with considerable accuracy upon a safe grade. One thing is sure, that our levees will have to be raised 3 feet to hold a flood like 1882, and allow any proper margin for contingencies. This, at a rough estimate, will require 10,000,000 cubic yards; to rebuild the gaps, about 500,000. The fact that our levees have given way in unexpected places, and in an unexpected manner, should not lend any color to the vulgar notion sometimes expressed that no confidence can be placed in levees, or as it is sometimes phrased, that "dirt can not be made to hold water." On the contrary, the experience of this year shows that by far the greater portion of our earth-works have stood a strain, which for magnitude and duration is utterly beyond precedent, with wonderful tenacity. If they have sometimes failed, it was because there was a good reason for it, and

so far from being discouraged, we should be stimulated to find out the cause and apply the remedy.

I think the cause has been discovered. The remedies may be threefold. First, to make borrow-pits, shallower, where sandy soil prevails, to keep them if possible from extending to the sand stratum at all; if not, to leave a berme of unusual width between them and the levee. Second, to dig a muck ditch of much greater width and depth than usual, penetrating entirely through the sand stratum, if practicable, and filled with buck-shot earth thoroughly tamped. Third, to build a banquette or bench on the land side, of sufficient width and height to hold down the upward pressure, and transfer it to a point where it will be so far weakened by distance and constant resistance as to be harmless. There is no question that the difficulties in the way of building sound and sufficient levees have been underrated. We have gone at the work in a rough-and-ready way, each man following in the footsteps of his predecessor, holding blindly to a rule-of-thumb method, without close inquiry into differences of circumstances. Slopes of three to one, with a crown of 8 feet, have been supposed to make a safe levee in any kind of soil. So far as the levees are concerned perhaps they do, but they do not afford a sufficient cover to a weak and treacherous foundation. A more minute and intelligent supervision will be henceforth necessary, and a stricter adherence to specifications.

The details of these matters must be reserved for more careful study.

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Respectfully,

WM. STARLING,
Chief Engineer.

REPORT OF MR. J. J. HOOPER, ASSISTANT ENGINEER, ON DISCHARGE OBSERVATIONS AT ARKANSAS CITY AND AT THE VARIOUS CREVASSES IN THE THIRD DISTRICT, 1890.

I submit herewith the results of the discharge observations at Arkansas City, and also gauging of the volume or water passing through the crevasses in the vicinity.

The party was organized March 6, 1890. The appliances were put in order and range signals relocated. The old discharge section was used in these observations, and as the intersecting signals were nearly all carried away by the high water, and the banks were overflowed, careful surveys were required to mark the ranges in their old positions. The first complete set of river-discharge measurements was made on March 14 and the last on April 15. In all fourteen complete gaugings were obtained, covering the time of highest water.

Two partial discharges were taken, which could not be made complete, owing to, in one case the failure of appliances, and in the other to obstruction of view, caused by ferry-boat *Marian*, lying at elevator. The accident to the *Vidalia*, and failure in appliances, made it impossible to obtain a discharge between March 19 and March 25, and the wind-storm of March 27 interfered on that date. More discharges would have been taken had the steam-boat been available, but the urgent necessity for its use in preserving the levees, and relieving the people overflowed, interfered with the use of the boat for this purpose.

CREVASSES.

The crevasses above the discharge section on the Mississippi side were Catfish Point, Easton, and Huntington, through all of which the water flowed from the river, and ten crevasses on the lower side of Catfish Point, through which the water flowed into the river from the break at Catfish, on the upper side of the point. The Offutt crevasse was below the discharge section.

The crevasses on the Arkansas side, above the discharge section, were at Brooksfield, Boggy Bayou, Sappington, Fergusom, Chicot, and one between Chicot and Arkansas City. The last-named flowed into the river after March 27.

With this exception the water from the other crevasses on this side and that flowing around the end of the levee at Amos Bayou is all discharged between Arkansas City and Trippe through and over the embankment of the Little Rock, Mississippi River and Texas Railroad.

The distance from the river-discharge section to Trippe is 7 miles. Three careful measurements were made of this discharge, which, as stated above, includes all the water passing through the crevasses on the right bank above the discharge section. The following is the method used in gauging the crevasses. The water flowing through Huntington and Catfish Point crevasses was measured with the current-meter.

Of that flowing through others, the velocity was obtained by the use of floats,

except a portion between Arkansas City and Trippe, being of small depth and flowing over the railroad embankment; the flow was treated as passing over a weir.

The floats used were two cones, each 6 inches in diameter and 6 inches high, joined at their base, and submerged to mid-depth. The time of passing two ranges of known distance apart was taken and the surface velocity computed.

In other instances the time taken for the float to travel the length of the skiff was used where ranges could not be obtained on account of backwater, the skiff being held in position by a line fastened to a tree. Eighty per cent. of the surface velocity was taken as the mean velocity.

The maximum discharge of Huntington crevasse was calculated from data obtained on April 1, but which was not complete, on account of the current being too strong to allow a complete set of soundings.

That of the crevasses on the lower side of Catfish Point was found by taking the increase of area resulting from the caving back of the ends of the levee, combined with the velocities found in the previous observations of March 12.

The maximum discharge of Offut's crevasse is from estimation 600 feet long, 7 feet deep, with velocity of 8 feet per second, as the first measurements, April 15, were not obtained until after the water had begun flowing back into the river, which began April 1.

In estimating the maximum discharge of Boggy Bayou, the original depth of the levee below the water-line, the width found in later observations, and a velocity of 7 feet per second were the data taken. A velocity of 6 feet per second was used for the Chicot, Brooksfield, and Ferguson crevasses.

The date of maximum discharge was generally taken at about three days after the break, as after that time the backwater retarded the flow through the crevasse.

The results obtained, with the locality and dates upon which measurements were made, are contained in the accompanying statement.

Method: The main river discharges were obtained from a steam-boat, with a current-meter, in the usual manner.

Eleven velocity sections were taken, and the soundings across the section spaced generally less than 75 feet apart; these were located by a transit stationed on the right bank, about 2,000 feet above the discharge section.

RATING CURRENT METERS.

Price meters Nos. 4 and 6 were used on the work. The former was rated twice and the latter once. All the observations for rating them were taken at Lucca Landing, in still water, over a base 1,000 feet long; about a dozen observations being made in each rating.

A steam-boat was used in this work, and the velocities ranged about 3 to 10 feet per second.

Results of discharge observations, Mississippi River, Arkansas City, Arkansas, 1890.

Date.	Area.	Gauge.	Difference.	Resulting difference in water areas.	Actual difference in water areas.	Scour +; Fill —	Datum area.
Mar. 14	206,615	48.00	.....	.....	.....	.....	184,568
19	222,638	48.66	+0.66	—2,257	+16,023	+13,766	198,342
25	225,579	49.01	+0.35	—1,197	+ 2,941	+ 1,744	200,090
26	228,326	49.22	+0.21	— 718	+ 2,747	+ 2,029	202,122
28	218,791	49.05	—0.17	+ 581	— 9,535	— 8,954	.....
30	231,370	48.62	—0.43	+1,470	+12,579	+14,049	207,211
31	227,722	48.66	—0.06	+ 205	— 3,647	3,443	203,767
Apr. 2	230,119	48.41	—0.15	+ 513	+ 2,397	+ 2,910	206,675
4	226,695	48.08	—0.33	+1,128	— 3,424	— 2,296	204,376
7	223,193	47.71	—0.37	+1,265	— 3,502	— 2,237	202,185
9	226,274	47.78	+0.07	— 240	+ 3,081	+ 2,841	204,977
11	233,503	47.70	—0.08	+ 274	+ 7,229	+ 7,503	212,497
13	241,545	47.60	—0.10	+ 342	+ 8,042	+ 8,384	220,861
15	237,359	47.55	—0.05	+ 171	— 4,186	— 4,015	216,846

Results of discharge observations, Mississippi River, Arkansas City, Arkansas, 1890.

[Width, 3,420 feet.]

Date.	Gauge-readings.	Gauge difference.	Dimensions of discharge section.			Scour + or fill—	Mean velocity per second.	Discharge per second.	Discharge outside of section.	Total discharge per second.
			Area.	Mean depth.	Maximum depth.					
Mar. 14	48.00	0.00	206,615	60.4	83	.....	5.714	1,180,659	5,000	1,185,659
19	48.66	+0.66	223,638	65.1	88.5	+18,214	6.335	1,410,441	8,000	1,418,441
25	49.01	+0.35	225,579	65.96	89.5	+ 4,138	5.364	1,210,124	10,000	1,220,124
26	49.22	+0.21	228,326	66.8	86	+ 2,465	5.685	1,298,010	10,000	1,308,010
28	49.05	—0.17	218,791	64.0	89	—10,116	5.544	1,212,919	10,000	1,222,919
30	48.62	—0.43	231,370	67.7	92	+11,109	5.369	1,242,231	8,000	1,250,231
31	48.56	—0.06	227,722	66.6	92	— 3,443	5.551	1,263,992	8,000	1,271,992
Apr. 2	48.41	—0.15	230,119	67.3	89	+ 1,884	5.790	1,332,330	7,000	1,339,330
4	48.08	—0.33	226,695	66.3	89	— 4,552	5.364	1,215,970	5,000	1,220,970
7	47.71	—0.37	223,193	65.3	89	— 3,662	5.300	1,183,001	4,000	1,187,001
9	47.78	+0.07	226,274	66.2	89.5	+ 3,321	5.373	1,215,849	4,000	1,219,849
11	47.70	—0.08	233,503	68.3	88	+ 6,955	5.122	1,195,964	3,500	1,199,464
13	47.60	—0.10	241,545	70.6	89	+ 770	5.513	1,331,745	3,000	1,337,445
15	47.55	—0.05	237,359	69.4	91	— 4,015	5.398	1,281,250	3,000	1,284,250

Measurement of crevasses below Arkansas City to be added to river discharge at Wilson's Point, Louisiana.

[Method used: Surface floats.]

Description of crevasses.	Locality on inch to mile map.	Bank.	Width.	Area.	Mean velocity.	Discharge, cubic feet per second.	Date of observation.	Date of crevasse.
			Feet.	*Sq. feet.*			1890.	
Offutt's*	444.5	L. B.	860	37,467	—0.37	—13,662	Apr. 15	
Lunat	467	R. B.	425	2,975	10.4	30,940	Mar. 19	Mar. 18
Do	467	R. B.	550	3,850	8.0	30,800	Mar. 22	Mar. 18 7 a. m.
Do	467	R. B.	625	4,062	7.2	29,246	Mar. 25	Do.
Do	467	R. B.	630	4,095	7.2	29,484	Mar. 26	Do.
Do	467	R. B.	730	4,380	6.0	26,280	Apr. 1	Do.
Do	467	R. B.	750	4,125	6.0	24,744	Apr. 4	Do.
Do	467	R. B.	760	4,180	5.6	23,408	Apr. 5	Do.
Do	467	R. B.	760	3,800	4.8	18,240	Apr. 8	Do.
Do	467	R. B.	760	3,800	5.2	19,760	Apr. 7	Do.
Do	467	R. B.	765	3,825	4.8	18,360	Apr. 9	Do.
Do	467	R. B.	765	3,825	4.4	16,829	Apr. 10	Do.
Do	467	R. B.	770	3,850	4.4	16,940	Apr. 11	Do.
Do	467	R. B.	770	3,850	4.0	15,400	Apr. 12	Do.
Do	467	R. B.	775	3,875	3.5	13,640	Apr. 14	Do.
Do	467	R. B.	775	3,720	3.4	12,499	Apr. 15	Do.
Point Chicot	472	R. B.	2,940	6,615	0.92	6,055	Mar. 12	Mar. 7

* Maximum discharge March 21, 35,000 cubic feet flowing into river after April 1.
† Measured by A. F. Kilpatrick. Maximum discharge March 19, 31,000 cubic feet.

Crevasse measurements in vicinity of Arkansas City, Arkansas, 1890.

Description of crevasse.	Locality on inch to mile map.	Discharge section.	Width.	Area.	Mean velocity feet per second.	Discharge cubic feet per second.	Date of observation.	Method used.	Date of crevasse.	Remarks.
			Feet.	*Sq. feet.*			1890.			
Brooks' Field Opossum Fork Levee.	.....	R. B.	590	0,404	4.00	25,622	Apr. 19	Surface floats ..	Mar. 27	Maximum discharge Apr. 3, 38,000 cubic feet.
Boggy Bayou	426	R. B.	273	10,800	2.44	26,489	Apr. 19	... do	Apr. 5	Maximum discharge Apr. 3, 44,000 cubic feet.
Sappington	429	R. B.	620	5,118	3.80	18,321	Apr. 17	....do	Mar. 9	Maximum discharge Mar. 12, 35,000 cubic feet.
Ferguson	426	R. B.	320	3,468	4.03	13,987	Apr. 17	....do	Mar. 27	Maximum discharge Mar. 31, 17,000 cubic feet.
Chicot	431.5	R. B.	240	1,700	4.85	8,241	Apr. 11	....do	Mar. 27	Maximum discharge Mar. 27, 10,000 cubic feet.
Between Chicot and Arkansas City	433	R. B.	354	2,480	5.84	14,483	Mar. 25	....do	Mar. 24	Maximum discharge Mar. 26, 17,000 cubic feet.
Do	433	R. B.	390	3,046	0.95	— 2,901	Apr. 17	....do	Mar. 24	Commenced flowing into river Mar. 28.
Drainage openings and crevasses between Arkansas City and Trippe, Ark.	.....	R. B.	16,180	111,013	1.24	137,500	Apr. 7 Apr. 8	....do	.....	Maximum discharge Apr. 10, 248,600 cubic feet.
Do	.....	R. B.	16,190	111,266	1.33	148,591	Apr. 9 Apr. 10	....do	.....	Do.
Do	.....	R. B.	15,000	106,162	1.32	140,558	Apr. 14 Apr. 16	....do	.....	Do.
Catfish Point	432	L. B.	1,718	36,257	5.73	207,851	Apr. 6	Meter	Apr. 4	Maximum discharge Apr. 6, 208,000 cubic feet.
Do	432	L. B.	1,969	43,281	4.72	204,500	Apr. 11	....do	Apr. 4	
Do	432	L. B.	1,969	43,011	4.72	203,173	Apr. 13	....do	Apr. 4	
Lower side of Catfish	431	L. B.	3,097	51,980	2.09	—108,647	Apr. 11 Apr. 13	Surface floats...	Apr. 4 Apr. 5	Flowing into river—maximum discharge Apr. 21, 114,000 cubic feet.
Do	432	L. B.	3,428	54,632	2.09	—114,000	Apr. 11 Apr. 13	....do	Apr. 4 Apr. 5	
Easton	435.2	L. B.	750	41,000	1.35	52,296	Apr. 4	....do	Mar. 28	Maximum discharge Apr. 13, 68,000 cubic feet.
Do	435.2	L. B.	776	41,000	1.43	58,752	Apr. 11	....do	Mar. 28	Area of section sounded below crevasse, 29,739 feet—area of section above, 21,581 feet.
Do	435.2	L. B.	780	41,000	1.65	67,650	Apr. 13	....do	Mar. 28	Do.
Huntington	438.5	L. B.	625	24,789	4.46	110,513	Apr. 10	Meter.	Mar. 28	Maximum discharge Apr. 1, 125,000 cubic feet.
Do	438.5	L. B.	625	23,049	4.31	99,513	Apr. 11	....do	Mar. 28	Commenced flowing into river, Apr. 1.
Do	438.5	L. B	625	21,376	4.36	93,244	Apr. 13	....do	Mar. 28	
Offutt's	444.5	L. B.	860	37,467	—0.37	—13,692	Apr. 15	Surface floats...	Mar. 18	Maximum discharge Mar 21, 35,000 cubic feet.
Columbia and Point Chicot	470	R. B.	5,000	25,725	1.28	33,034	Mar. 31	....do	Mar. 28, 4 a. m.	
Do	470	R. B.	5,850	26,905	1.31	35,214	Apr. 3	....do	.....	
Do	470	R. B.	5,850	27,655	1.24	34,402	Apr. 4	....do	.....	Maximum discharge Apr. 3, 35,200 cubic feet.
Do	470	R. B.	5,850	26,480	1.21	31,984	Apr. 5	....do	.....	
Do	470	R. B.	5,850	26,130	1.27	33,144	Apr. 7	....do	.....	
Do	470	R. B.	5,850	25,710	1.11	28,515	Apr. 11	....do	.....	
Do	470	R. B.	5,850	24,170	1.01	24,464	Apr. 14	....do	.....	
Do	470	R. B.	5,850	25,380	0.98	24,947	Apr. 15	....do	.....	

Crevasse measurements in vicinity of Arkansas City, Arkansas, 1890—Continued.

Description of crevasse.	Locality on inch to mile map.	Discharge section.	Width.	Area.	Mean velocity feet per second.	Discharge cubic feet per second.	Date of observation.	Method used.	Date of crevasse.	Remarks.
			Feet.	*Sq. feet.*			1890.			
Miller's Bend	474	L. B.	300	.....	.....	.....	.....	.....	Apr. 7	Discharging into river, maximum discharge April 15, 10,000 cubic feet (estimated).
Skipwith's	530	L. B.	1,020	34,116	1.89	64,636	Apr. 2	....do	Mar. 26	Measured by Surveyor F. P. Spalding.
Do	530	L. B.	1,020	40,063	2.12	84,886	Apr. 5	Meter	.....	
Do	530	L. B.	1,020	39,839	1.91	76,218	Apr. 9	....do	.....	Maximum discharge Apr. 5, 84,900 cubic feet.
Do	530	L. B.	1,020	40,424	1.96	79,130	Apr. 14	....do	.....	
Do	530	L. B.	1,020	42,075	1.80	75,910	Apr. 17	....do	.....	
Do	530	L. B.	1,020	41,174	1.58	65,191	Apr. 19	....do	.....	
Do	530	L. B.	1,020	42,507	1.70	72,186	Apr. 24	....do	.....	
Do	530	L. B.	1,020	42,210	1.55	65,484	Apr. 28	....do	.....	
Do	530	L. B.	1,020	39,970	1.09	43,378	May 2	....do	.....	
Do	530	L. B.	1,020	38,728	0.97	37,610	May 6	....do	.....	

REPORT OF MR. FRED P. SPALDING, UNITED STATES SURVEYOR, ON DISCHARGE OBSERVATIONS AT WILSON'S POINT, LOUISIANA, AND AT SKIPWITH CREVASSE, MISSISSIPPI, 1890.

Observations for the discharge of the river at Wilson's Point, La., were made, beginning on January 27, 1890, and ending on May 7, 1890, during which time a continuous series of observations was kept up of the main river, and after its occurrence, of the Skipwith Crevasse. The observations were taken from the steam survey-boat *Meter*, which during the observation was held by the pilot as nearly as possible upon a point fixed by the intersection of two ranges marked upon the bank. The section used was the same one upon which the observations of 1888 and 1889 were made.

A "Price" current meter was used, and was lowered from the side of the steamboat by a wire rope to six-tenths of the depth of water at each point; a lead of 225 pounds weight was used to sink the meter to the proper depth, and a guy-wire leading to the bow of the boat, to keep it in place vertically. Readings were taken each minute for five consecutive minutes, and a mean of the readings used in the computations. The meter was rated three times during the continuance of the observations, by being held over the bow of a skiff, which was towed by the men along a base-line on the levee, once near Skipwith's and twice at Wilson's Point.

At the break in Skipwith's Levee, observations were taken from a skiff held in place with the oars; the meter was lowered from the bow of the skiff upon an ordinary lead line, with a 20-pound lead to sink it to the proper position. The registrations were counted for a single minute, commonly repeated as a check upon its accuracy, and, as in the main channel, at six-tenths of the depth of water.

As the section measured was located directly across the break through the deep water resulting from the scour, it was thought advisable to take some observations for the purpose of determining if the flow through the break would be fairly measured by this method; and for this purpose, at various times, velocities were taken at every 5 feet of depth in a vertical line at different points in the section. The result of these observations may be briefly stated as seeming to show a quite steady flow through the break, with an average velocity about eight-tenths of that at the surface, and in general correctly represented by the velocity at five-tenths to six-tenths of the depth.

In accordance with general instructions, copies of the field notes have been sent for computation in the office of the Secretary of the Mississippi River Commission.

A table is herewith presented showing results of the field computations:

Results of discharge observations at Wilson's Point, Louisiana, as shown by field computations.

Date.	Wilson's Point gauge-reading.	Lake Providence gauge-reading.	Area channel section, 1,000 square feet.	Wilson's Point, La. (main river).					
				Velocity on channel section, 5 feet per second.	Through channel section, 1,000 cubic feet.	Over east bank, 1,000 cubic feet.	Total.	Slopes (on Louisiana side).	
								For 2,000 feet above section.	For 2,500 feet below section.
1890.									
Jan. 28	34.95	.....	148	7.38	1,088	.....	1,088	.00080	.00108
31	36.05	.....	150	6.98	1,050	.....	2,050	.00085	.00116
Feb. 3	36.96	37.15	156	7.51	1,176	.....	1,176	.00075	.00116
4	37.20	37.40	166	7.03	1,164	.....	1,164	.00090	.00108
5	37.42	37.57	159	6.87	1,093	5	1,098	.00085	.00116
6	37.59	37.80	164	6.85	1,120	8	1,128	.00075	.00124
8	38.10	38.30	171	6.85	1,173	16	1,189	.....	.....
10	38.40	38.52	178	6.83	1,214	20	1,234	.00085	.00112
11	38.45	38.57	176	6.70	1,182	23	1,205	.00095	.00108
12	38.44	38.60	174	6.40	1,111	23	1,134	.00095	.00112
13	38.45	38.70	173	6.31	1,092	23	1,115	.00080	.00128
14	38.56	38.70	177	6.36	1,124	25	1,149	.00085	.00120
15	38.56	38.70	175	6.18	1,078	25	1,103	.00060	.00108
17	38.62	38.77	176	6.14	1,078	26	1,104	.00075	.00108
20	38.95	39.00	178	5.98	1,064	28	1,092	.00105	.00108
21	39.00	39.13	180	6.33	1,139	28	1,167	.00075	.00112
22	39.15	39.23	182	6.02	1,098	29	1,127	.00090	.00120
24	39.38	39.42	179	6.22	1,114	30	1,144	.00075	.00120
25	39.44	39.47	181	6.11	1,106	30	1,136	.00075	.00116
26	39.44	39.50	180	5.97	1,076	30	1,106	.00075	.00016
27	39.55	39.57	184	5.91	1,084	31	1,115	.00060	.00112
Mar. 1	39.35	39.40	180	5.80	1,045	30	1,075	.00075	.00112
3	39.40	39.45	184	5.91	1,088	30	1,118	.00090	.00112
4	39.48	39.54	185	5.77	1,067	31	1,098	.00085	.00112

Results of discharge observations at Wilson's Point, Louisiana, etc.—Continued.

Date.	Wilson's Point gauge-reading.	Lake Providence gauge-reading.	Area channel section, 1,000 square feet.	Wilson's Point, La. (main river.)					
				Velocity on channel section, 5 feet per second.	Through channel section, 1,000 cubic feet.	Over east bank, 1,000 cubic feet.	Total.	Slopes (on Louisiana side).	
								For 2,000 feet above section.	For 2,500 feet below section.
1890.									
Mar. 5	39.62	39.64	186	5.94	1,103	33	1,136	.00080	.00112
6	39.70	39.82	191	6.01	1,146	34	1,180	.00075	.00112
7	39.98	40.00	193	5.81	1,122	40	1,162	.00070	.00108
8	40.10	40.19	196	.....	1,143	43	1,186	.00060	.00112
10	40.43	40.45	198	.....	1,183	47	1,230	.00075	.00100
11	40.47	40.50	199	.....	1,241	47	1,288	.00085	.00104
12	40.73	40.75	203	5.62	1,141	50	1,191	.00075	.00104
13	40.85	40.90	204	5.54	1,129	50	1,179	.00070	.00096
14	40.88	40.92	205	5.67	1,165	50	1,215	.00060	.00100
15	40.98	41.05	200	5.87	1,171	50	1,221	.00060	.00100
17	40.90	40.67	200	5.92	1,186	47	1,233	.00060	.00104
18	40.86	40.55	199	6.11	1,219	45	1,264	.00075	.00104
19	40.60	40.40	197	6.06	1,195	38	1,233	.00075	.00104
20	40.47	40.25	200	5.66	1,131	35	1,166	.00075	.00104
21	40.46	40.23	201	5.44	1,092	35	1,127	.00075	.00104

Results of discharge observations, Wilson's Point, Louisiana, as shown by field computations.

Date.	Wilson's Point gauge.	Lake Providence gauge.	Area of channel section, 1,000 square feet.	Wilson's Point, La.				Main river slopes to—		Skipwith's Crevasse.	
				Velocity in channel section, feet per second.	Through channel section, 1,000 cubic feet per second.	Discharge per second.		2,000 feet above section.	2,500 feet below section.	Area of section.	Discharge, cubic feet per second.
						Over east bank.	Total.				
1890.										*Sq. feet.*	
Mar. 24	40.48	40.22	201	5.83	1,173	35	1,208	.00075	.00100	.....	.....
25	40.50	40.25	200	6.08	1,219	35	1,254	.00065	.00100	.....	.....
28	40.22	39.90	199	5.95	1,186	30	1,216	.00065	.00092	.....	.....
31	39.75	39.60	196	5.98	1,174	25	1,199	.00060	.00100	.....	.....
Apr. 2	39.72	39.45	196	5.85	1,148	23	1,171	.00060	.00096	34,116	64,656
3	39.85	39.57	197	6.04	1,187	23	1,210	.....	.00084	.....	.....
4	39.60	39.40	196	5.99	1,175	21.5	1,197	.00085	.00092	.....	.....
5	39.45	39.30	196	5.74	1,124	20	1,144	.00070	.00092	40,063	84,886
7	39.45	39.30	195	5.79	1,127	19	1,146	.00060	.00072	.....	.....
8	39.45	39.30	196	5.70	1,117	18	1,135	.00060	.00072	.....	.....
9	39.45	39.30	196	5.62	1,103	17	1,120	.00060	.00072	39,839	76,218
10	39.40	39.30	192	5.73	1,102	16	1,118	.00060	.00072	.....	.....
11	39.40	39.30	192	5.72	1,098	15	1,113	.00060	.00072	.....	.....
12	39.40	39.30	192	5.91	1,137	15	1,152	.00060	.00072	.....	.....
14	39.40	39.30	193	5.59	1,079	15	1,094	.00060	.00072	40,424	79,130
15	39.30	39.25	196	5.60	1,098	14	1,112	.00060	.00088	.....	.....
17	39.30	39.30	194	5.52	1,072	14	1,086	.00045	.00084	42,095	75,910
18	39.25	39.25	194	5.57	1,081	13	1,094	.00040	.00088	.....	.....
19	39.18	39.27	196	5.52	1,081	12	1,093	.00045	.00088	41,174	65,191
21	39.22	39.35	191	5.71	1,093	12	1,105	.00055	.00080	.....	.....
22	39.21	39.33	192	5.61	1,078	12	1,090	.00050	.00088	.....	.....
24	39.25	39.40	194	5.75	1,116	12	1,128	.00070	.00084	42,507	72,186
25	39.18	39.27	195	5.63	1,096	11	1,107	.00050	.00088	.....	.....
26	38.95	39.05	196	.....	1,091	9	1,100	.00055	.00092	.....	.....
28	38.50	38.70	189	5.48	1,038	5	1,043	.00060	.00080	42,210	65,484
29	38.30	38.52	189	5.48	1,027	0	1,027	.00060	.00100	.....	.....
30	38.18	38.40	186	5.53	1,030	.....	1,030	.00060	.00088	.....	.....
May 2	37.98	38.15	186	5.51	1,023	.....	1,023	.00050	.00088	39,970	43,378
5	37.90	38.00	189	5.38	1,018	.....	1,018	.00050	.00080	.....	.....
6	37.75	38.87	190	5.36	1,017	.....	1,017	.00050	.00100	38,728	37,610
7	37.65	37.85	190	5.17	981	.....	981	.00060	.00092	.....	.....

NOTE.—The observed discharges at Skipwith Crevasse are given in table in report of J. J. Hoopes, assistant engineer.

FINANCIAL STATEMENT.

High-water protection of levees.

Balance May 31, 1889		$20,000.00
Received by transfer from Lake Providence allotment		55,000.00
General service allotment		20,000.00
Maintenance of works, first district		27,250.00
Lake Bolivar allotment		5,000.00
By overpayment of voucher		3.00
		127,253.00
Expenditures apportioned for—		
Administration and office expenses	$1,474.23	
Material for protection	59,533.20	
Subsistence	5,262.98	
Transportation and travel expenses	639.62	
Steamer expenses	11,262.68	
Labor on protection	48,332.86	
		126,505.57
Balance June 30, 1890		747.43

All of which is pledged.
Amount that can be profitably expended in fiscal year ending June 30, 1892 $10,000.00

PROTECTION OF LEVEES—THIRD DISTRICT.

Financial statement.

Balance May 31, 1889		$3,701.57
Expended and apportioned for—		
Administration and inspection	$393.56	
Material for repairs and protection	1,642.23	
Labor for repairs and protection	1,646.00	
Miscellaneous	19.78	
		3,701,57

OBSERVATIONS AND DISCHARGES.

Discharge measurements were made by Assistant Engineer Tollinger at Wilson's Point, in July, 1889. The field computations gave the following discharges:

Date.	Wilson's Point gauge.	Discharge.
1889.	*Feet.*	*Cubic feet.*
July 3	29.20	856,000
July 4	28.87	861,000
July 5	28.30	792,000

Discharge observations, during the flood of 1890, were made at Wilson's Point, La., Arkansas City, Ark., and at the several crevasses. A report on these observations, with tables of results, is given under the heading "High-water protection of levees and the flood of 1890," which see.

OBSERVATIONS AND DISCHARGES, THIRD DISTRICT.

Financial statement.

Balance May 31, 1889		$82.38
Expended for—		
Fuel	$41.50	
Stationery	40.88	
		82.38
Amount that can be profitably expended in fiscal year ending June 30, 1892		5,000.00

GAUGES, THIRD DISTRICT.

The river gauges in the third district, at Clarendon, Ark., Arkansas City, Ark., Greenville, Miss., and Yazoo City, Miss., have been maintained and read during the year and the weekly gauge reports forwarded to the Secretary of the Commission for computation.

Financial statement.

Balance May 31, 1889		$1,229.65
Expended for—		
Pay of observers	$720.00	
Traveling expenses	10.75	
		730.75
Balance June 30, 1890		498.90
In treasury	300.00	
In hand	198.90	
		498.90
Less liabilities		180.00
Available balance, June 30, 1890		318.90
Amount that can be profitably expended during fiscal year ending June 30, 1892		$1,000.00

LEVEES.

The only work done in levee-building during the year was in enlarging a weak place in the levee south of Lakeport, Ark., 8,419¼ cubic yards of earth being here added to the levee. The work was done by Mr. E. Hyner, under verbal agreement, at 18 cents per cubic yard.

LEVEES, TENSAS FRONT IN ARKANSAS.

Financial statement.

Balance May 31, 1889		$2,057.79
Expended and appertioned for—		
Administration and inspection	$488.41	
Repair and enlargement	1,515.51	
Subsistence	15.30	
Miscellaneous	38.57	
		2,057.79
Amount that can be profitably expended in fiscal year ending June 30, 1892		2,000,000.00
For levees Yazoo front:		
Amount that can be profitably expended in fiscal year ending June 30, 1892		1,000,000.00

LEVEES, SECOND MISSISSIPPI DISTRICT.

Financial statement.

Balance May 31, 1889		1,649.32
Expended for—		
Repairs to levees	$113.64	
Transferred to surveys, examinations, and inspections	1,535.68	
		1,649.32

LEVEES, YAZOO FRONT, BEN LOMOND HOOF.

Financial statement.

Balance May 31, 1889	613.78
Transferred to surveys, examinations, and inspections	613.78

SURVEYS, EXAMINATIONS AND INSPECTIONS.

A list of the surveys made during the year previous to May, with a description of the results found, is given in the following report of Mr. Fred Spalding, surveyor.

Two parties were sent out in May, one to Lake Providence Reach, under Mr. William P. Richards, draughtsman, and one to the Greenville Bends, under Mr. Fred Spalding, surveyor, to locate the shore-lines, for comparison with previous surveys.

Maps of Lake Providence Reach and of the Greenville Bends, showing changes in the shore-lines to May, 1890, and of Greenville Harbor are herewith. The survey of Greenville Harbor made in October and November, 1889, showed that the dikes constructed in 1887 were in good condition and that no change had taken place in the shore-line.

Rapid caving is going on at Caulk's Point, at the Greenville Bends, and at several points in Lake Providence Reach.

Cut-offs are more or less threatened at Caulk's Point and at the several Greenville Bends; but no immediate danger from caving exists, except at Ashbrook Point. The distance across the neck from Georgetown Bend to Miller's Bend was, in 1882, 4,000 feet; in July, 1890, 2,700 feet; and in May, 1890, 2,400 feet.

Caving is most rapid during the time the river is falling from a high to a medium stage. As the river is still high, it is probable that very rapid caving will occur during the next few months, and that the distance above given will be considerably reduced by the time revetment work could be begin in the fall.

A cut-off here would prove extremely injurious to the river, to existing improvements below, and to riparian interests. To surely prevent it work should be begun at once, and funds for properly revetting the part of the bank in Georgetown Bend immediately in front of the narrow neck should be allotted from the very next appropriation. If this is not done, the failure of the river and harbor bill for one or two succeeding years may delay the work so long as to permit the threatened cut-off to take place.

The United States should, I think, acquire title to the land comprised in the several necks, so that they can be kept covered with a thick forest growth, to check the current running across the necks in time of high water. As a further protection against cut-offs a high, strong levee should be built along the axis of each neck, to entirely prevent the water from running across it.

REPORT OF MR. FRED. F. SPALDING, SURVEYOR, ON SURVEYS, EXAMINATIONS, AND INSPECTIONS MADE DURING THE YEAR ENDING MAY 31, 1890.

Surveys have been made in the following localities: Lake Bolivar Front, Caulk's Point, the Greenville bends, Greenville Harbor, Lake Providence Reach.

LAKE BOLIVAR FRONT.

An examination of Lake Bolivar Front was made in June, 1889, with soundings over the revetment work for the purpose of determining the position and condition of the work, a report of which, with map, was at that time submitted.

CAULK'S POINT.

The survey of the river in vicinity of Caulk's Point, Arkansas, was made in June, 1889, for the purpose of showing the changes which have occurred in shore-lines since the survey of 1881-'82, and to determine the probability of a cut-off across the neck. As was shown by the measurement of this neck, given in the last Annual Report, its width has been reduced from 5,800 feet in 1882 to 3,900 feet, with rapid caving still in progress in the most narrow part. Although the ground here is quite low, the neck is so fully covered by thick forest growth that it is not thought any considerable current could exist across it at high water.

The length of caving bank to be protected in the bend above the neck, to prevent the making of the cut-off, is at present above 2¼ miles. The survey was not extended above this bend, and no examination of the river has been made to determine the probable permanence of the existing conditions.

The map of this survey, already submitted, gives shore-lines of 1882 and present shore-lines from Wildwood Point to Catfish Point, a distance of about 18 miles, and shows soundings in the bend above the neck and location of the work upon Bolivar Front.

THE GREENVILLE BENDS.

The Greenville bends consist of five contiguous bends, beginning a short distance below Arkansas City, Ark., and extending about 40 miles to a point a few miles below Greenville, Miss. These bends are separated by four narrow necks of land, the cutting through of each of which is, to a greater or less extent, threatened by caving banks above.

In the upper or Ashbrook neck the width since 1882 has been diminished from about 4,000 feet to about 2,700 feet, and present conditions are favorable to a continuation of the caving at a still more rapid rate. The upper bank is of light material, and the current in the bend above strong and close against it.

The locality of rapid caving extends at present for some distance above the narrow part of the neck, and as the caving in the bend above Offutt's Landing tends to throw it lower in Georgetown Bend, it will continue to strike the weak point with increasing force. The caving bank requiring protection begins at Offutt's Landing and extends about 4 miles around Georgetown Bend.

In Rowdy Bend the caving bank begins at Gaines's Landing and extends about 4 miles down the bend. Below this point some caving occurs, but to a minor degree.

The least width of the Panther Forest Neck is 8,000 feet, and the caving since 1882 amounts to about 1,000 feet. The large Panther Forest levee, however, is within about 1,000 feet of the bank at the point of most rapid caving, and will soon be placed in danger.

In Miller's Bend the caving is slight, especially in the vicinity of Tarpley Neck, which is about 4,100 feet wide. The land is high and under cultivation.

The Leland Neck is high ground and under cultivation, but little caving is taking place in the bend above, in vicinity of the Neck, although at a point higher up, between Linwood and Pastoria Landing, it is considerable.

Maps have been already submitted of this survey, showing on small scale (1 : 300,000) the shore bar and levee lines of the entire reach, and on larger scale (1 : 10,000) separate sheets giving soundings in the three upper bends. A map will also be submitted with this report showing changes in shore-lines to the present month.

As the water is still at a high stage, it is proper to notice that this map will not represent the full effect of the present high-water season, which will be greatest during the time of falling to medium stage.

GREENVILLE HARBOR.

A survey of Greenville Harbor was made in October and November, 1889, to show the condition of the dikes and their effect upon the channel depths. A map of this survey was at that time submitted.

LAKE PROVIDENCE REACH.

Caving has continued on the head of Sarah's Island and in the lower part of Louisiana Bend. Heavy caving has taken place on the front of Island 92. A considerable portion of the upper part of Skipwith's Tow-head has washed away.

At Wilson's Point the caving is less rapid than formerly, and at Mayersville it is lower down, with a tendency of the main channel to take the west side of the middle bar.

At and below Longwood, La., heavy caving continues, as also on the Mississippi side near Shipland Landing. The main channel has been transferred from the Louisiana shore to outside the middle bar below Dessona Landing. A map will be presented with this report showing changes in shore-line to the present month.

Soundings over the newly completed work in Louisiana Bend were made in December, 1889, for the purpose of comparison with like soundings to be taken after the present high water has subsided.

The surveys made in May, 1890, show recent changes of shore-line at Lake Providence Reach and in the Greenville bends. Maps of these surveys are herewith submitted; they show in general a continuation of the conditions already stated.

LAKE PROVIDENCE REACH.

On the point at head of Sarah's Island the width of caving since the survey of May, 1889, is about 1,200 feet, causing the current to strike the banks correspondingly lower in Louisiana Bend, and changing to some extent the location of caving.

The caving in Louisiana Bend during the last year has been mainly below the landing at Pilcher's, in and below the head of Old River; it extends lower than is shown by other recent surveys, and is heaviest near the lower end, reaching a maxi-

mum width of about 1,000 feet and averaging about 600 feet for a distance of 2½ miles below the end of the revetment works.

As the caving still continues rapidly on Sarah's Island, it is evident that caving in the bend will go lower, and make it necessary that the revetment be carried throughout the bend to a point at least 3 miles below the end of the present work. On Island 92 the width of caving is about 300 feet, and extends a distance of 1½ miles.

A piece of Skipwith's Tow-head about 1,500 feet wide has been cut off; at Mayersville and below the caving averages about 200 feet wide for a distance of 2 miles.

A small caving is shown just below Homochitta Landing, due no doubt to the change, already noted, of the main channel to the west side of the bar opposite Mayersville, and showing the tendency to a shifting of the scene of caving from the vicinity of Mayersville to the bank just above and at the head of the baleshed dikes.

From Longwood to near Lake Providence the caving during the year ranges from about 300 to 600 feet in width for a distance of 4 miles, and at Shipland Point it is about 500 feet wide and 1 mile in length.

THE GREENVILLE BENDS.

In Georgetown Bend the maximum caving is shown to be in the narrow part of the Ashbrook Neck, which has decreased in width by over 300 feet since the survey in July, 1889, leaving an effective width of about 2,400 feet. The extent of caving is, as stated, about 4 miles.

In Rowdy Bend the principal caving reaches an average width of about 200 feet, and the distance to the Panther Forest Levee from the edge of the bank has decreased to about 800 feet.

At the time of making the survey in Rowdy and Georgetown bends the water was still near the top of bank in the concave portions, the process of caving was in full operation, and it seems probable that the new lines given do not by any means represent their probable position at the next low-water season.

In Miller's Bend the caving for the season is more than was anticipated at and below the Tarpley Neck, having reached an average of about 200 feet in width and reduced the width of the neck to 4,000 feet. In the upper part of the bend the caving is slight.

There has been no considerable caving in Spanish Moss Bend during the season, except at the lower end, at Point Chicot, where for a distance of 2 miles it has an average width of about 400 feet.

In Bachelor's Bend the head of caving is somewhat lower than formerly, on account of the rapid caving at Point Chicot. It begins about 1 mile above Barnes's Landing and extends to the protection work at Greenville, a distance of 2½ miles, with an average width of 300 feet.

No caving has taken place in vicinity of the dikes in front of the town; above them, however, and below those more recently placed, as well as between the two upper dikes, the bank has caved in pockets.

The caving from above has also gone behind the upper mattress and taken the bank from under it.

Indications at present are that unless the work be extended above to protect the upper part of the bend caving from that direction will get behind and undercut the work now in place.

FINANCIAL STATEMENT.

Surveys, examinations, and inspections.

Balance May 31, 1889		$2,685.76
Received by transfer from levees Yazoo Front, Ben Lomond Hoop		613.78
Received by transfer from levees second Mississippi district		1,535.68
Received by transfer from Lake Bolivar Front		3,000.00
Total		7,835.22
Expenses apportioned for:		
Administration and inspection	$3,966.35	
Steamer expenses	3,231.01	
Subsistence	500.22	
Miscellaneous	75.38	
		7,772.96
Balance on hand June 30, 1890 (all of which is pledged)		62.26
Amount that can be profitably expended in fiscal year ending June 30, 1892		10,000.00

During the year ending May 31, 1890, there have been no new transportation lines established, nor any addition to the tonnage of any of the cities contained in this district.

Maps, lists of civilian engineers employed on work of river and harbor improvement, third district, and list of plant belonging to the United States, and used upon Mississippi River, third district, with its approximate value, May 31, 1890, accompany this report.

Very respectfully, your obedient servant,

W. YOUNG,
Captain of Engineers.

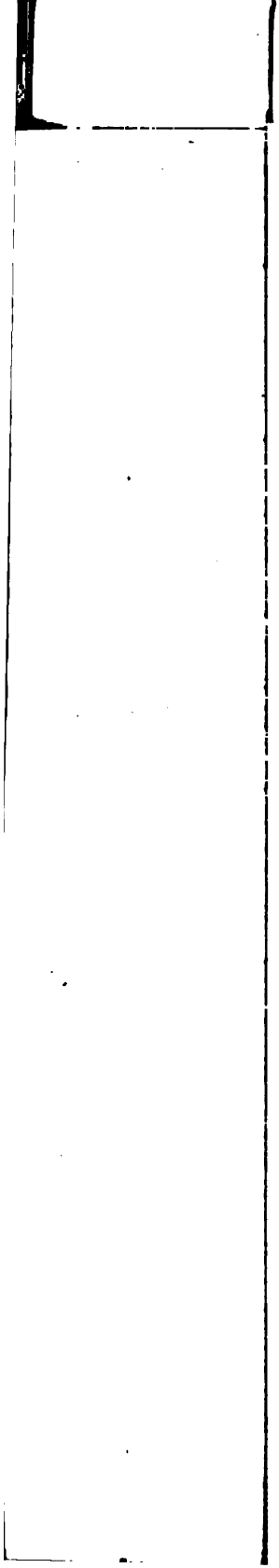
Col. C. B. COMSTOCK,
Corps of Engineers, Bvt. Brig. Gen., U. S. A.,
President Mississippi River Commission.

Approximate value of plant belonging to the United States and used upon the Mississippi River, third district, May 31, 1890.

Class of property.	No.	Approximate value, May 31, 1890.	Class of property.	No.	Approximate value, May 31, 1890.
Steam-boat *Emma Etheridge*	1	$13,500	Machine shop (with outfit)	1	$3,000
Steam-boat *Osceola*	1	10,800	Carpenter shop (with outfit)	1	600
Steam-boat *Vidalia*	1	9,400	Pile-drivers and machinery	16	16,000
Steam-boat *Meter*	1	4,000	Small scow	1	20
Steam-tug *Parker*	1	6,000	Yawls	7	210
Mattress-boats	5	7,500	Skiffs	42	630
Quarter-boats	1	2,000	Tools and appliances	....	1,000
Quarter-boats (with outfit)	10	10,000	Office furniture, safe, etc	....	200
Quarter-boats (with outfit)	3	1,500	Menge dredge	1	30,000
Hydraulic graders	2	24,000	Dump scows	2	10,000
Barges (square decked)	33	22,100	Surveying instruments	....	2,000
Barges (square decked)	6	1,800			
Barges (model)	10	16,000	Total		192,360.00

List of civilian engineers employed on work of river and harbor improvement in charge of Capt. William T. Rossell, Capt. S. S. Leach, and Capt. W. Young, Corps of Engineers, from May 31, 1889, *to May* 31, 1890 (*inclusive*), *under the river and harbor appropriation act approved August* 11, 1888.

Name and residence.	Time employed. M.	Time employed. D.	Compensation per month.	Where employed.	Work on which employed.
Arthur Hider, Louisville, Ky.	7		$200	Ashton, La	Revetment of Louisiana Bend.
	2		200	Greenville, Miss.	Charge of repairs to plant and care of property.
	2		200	Greenville, Miss.	Protection of levees during high water.
H. St. L. Coppée, Vicksburg, Miss.	2	5	175	Ashton, La	Revetment of Louisiana Bend.
	2	22	175	Greenville, Miss.	Building dikes in Greenville Harbor.
	1		175	Bolivar, Miss	Repairing revetment Lake Bolivar Front.
	6	3	175	Vicksburg, Miss.	Repairing dam and dike in Vicksburg Harbor. Charge of dredging.
E. C. Tollinger, Wrightsdale, Pa.	7		160	Ashton, La	Revetment of Louisiana Bend.
	2		160	Greenville, Miss.	Repairs to plant and charge of property.
	3		160	Arkansas City, Ark.	Protection of levees during high water.
Henry Goodrich, Lake Providence, La.	1	16	175	Ashton, La	Levees Tensas Front.
	2	22	175	Grand Lake, Ark.	Do.
	2	8	175	Raleigh, La	Protection of levees during high water.
John J. Hoopes, Arkansas City, Ark.	2		150	Arkansas City, Ark.	Discharge observations.



APPENDIX I.

REPORT OF CAPTAIN DAN C. KINGMAN, CORPS OF ENGINEERS, UPON OPERATIONS IN THE FOURTH DISTRICT.

UNITED STATES ENGINEER OFFICE,
New Orleans, June 13, 1890.

COLONEL: I have the honor to transmit herewith my annual report for works under my charge in fourth district, Mississippi River, for the period from July 1, 1889, to June 1, 1890.

Very respectfully, your obedient servant,

DAN C. KINGMAN,
Captain of Engineers.

Col. C. B. COMSTOCK,
Corps of Engineers, U. S. A.,
President Mississippi River Commission.

THE CONSTRUCTION OF LEVEES ON THE TENSAS FRONT, FOURTH DISTRICT.

At the date of my last annual report but little work was in progress in levee construction. The Hard Times-Wilson Levee was under contract and was about three-quarters completed. Work upon this levee was carried on by the contractor until the 7th of February, 1890, when the levee was reported finished. It was inspected and received by me February 12, 1890. It was a very large levee, containing 710,163 cubic yards of earth-work, and, including protection-levees and drainage-ditches that were required to be made during its construction, it was necessary to move 798,787 cubic yards of earth. The length of the levee was 53,564 feet, and including protection-levees it was 60,610 feet. It was the largest single levee ever built by the United States on the Mississippi River. The country through which it is constructed was much of it swampy and covered with heavy timber. It was also cut up by lakes and sloughs in such a way that the location was a very difficult one to make. For a portion of its length the levee ran upon a ridge between two lakes, which ridge was so narrow that there was barely room for the levee to rest upon, and in order to secure earth to build it with it was necessary to cut a very long ditch out to the river to partially drain these shallow lakes and uncover the ground upon which the barrow-pits could be placed. At one place the levee had to cross a channel which connected two of these lakes. It was believed that the bottom of this channel would form a very imperfect foundation, and to make the levee secure it was necessary to construct two dams across the channel, at a proper distance apart, in order to form a coffer from which the water could be pumped. After the water was pumped out the logs and fallen trees were removed from this base and two muck ditches were excavated and afterwards filled with good soil. Upon the foundation thus prepared an exceptionally strong levee was erected. It withstood the flood without injury at this place and without serious settlement. It may now be considered safe.

In the latter part of January, 1890, the bank of the river at Point Pleasant, a mile or two above Hard Times-Wilson Levee, began to cave very rapidly and threatened to breach the levee at that point, and so to flank the new levee. To prevent this, it was proposed to construct a new levee at a considerable distance in the rear of the old one. Its construction was commenced by the contractor of the Hard Times-Wilson Levee in February, but owing to the heavy rains and the trouble with seepage water, he made little progress and finally suspended work. Nothing is being done there at present, and the United States inspector has been temporarily withdrawn.

THE PROTECTION OF LEVEES DURING HIGH WATER.

As there was a small sum available for the protection of levees on the Tensas Front during high water, I caused an examination of all the United States levees in my district to be made during the months of November and December, with a view to ascertain where repairs were necessary. A line of levels was run over them all and the result was generally very favorable. But few of the levees were found below grade, and these only for comparatively short distances. The Hard Times Levee where it crosses the bed of Lake St. Joseph was low. Some portions of Evergreen Levee were also low and the same was true of Kempe Levee. Arrangements were accordingly

made to have these levees raised to the proper height. Work at Lake St. Joseph commenced the latter part of February and completed in March. On Kempe Le work was commenced in February and it has not yet been entirely completed, ow to the high stage of the river, which rendered it impossible or very expensive to earth. But the force of labor which had been gathered to repair this levee was to very good advantage subsequently to protect it from the flood. Nothing has been done at Evergreen in the way of permanent repairs. On the 12th of March, I received telegraphic information that $25,000 had been allotted to me for prote of levees on the Tensas Front. I accordingly sent the steam-boat *General Newton*, a barge in tow, in charge of Assistant Engineer H. S. Douglas, to the Tensas Fr The barge was loaded with sacks, lumber, tarpaulins, chains, twine, nails, etc., used for the protection of levees. At Simmesport I joined the boat myself, and I a there to the cargo a large number of wheelbarrows and shovels, and proceeded to m an inspection of levees on the Tensas Front. My plan was to aid the people in pro ing the levees, to make as much use as possible of the local organizations for l purposes, and to employ local labor to do the necessary work. I endeavored, w the planters were able to do so, to induce them to furnish the necessary labor to tect their own fronts, the United States furnishing material and such tools and neering assistance as was necessary. Where the work was of considerable magnit or where it was inaccessible or a long distance away from the plantations and pl where the laborers lived, I then hired the forces, and if necessary furnished with tools and subsistence. At this time the river was falling a little, and there peared to be no immediate danger, but I was satisfied that when the Yazoo w returned to the river that it would cause a second rise which would probably ex the first. In the mean time the Morganza Levee, in Pointe Coupée Parish, had reported in a dangerous condition, and funds for its protection had been provided the commission. I accordingly telegraphed to New Orleans to have material shi to Red River Landing, and directed Assistant Engineer W. G. Price to receive it distribute it where needed, and for this purpose to make use of boats and barge longing to the Atchafalaya River improvement. Other funds were afterward vided by the Commission to be used for protecting levees, generally in the fourth trict, and soon after all the restriction as to the use of money for levee protec was removed.

I returned to New Orleans March 20, and there chartered the steam-boat *Par* which I loaded with tools, material, etc., and proceeded to Pointe Coupee to as maintaining the levees upon this front, which I regarded as the most exposed of t all. I knew that a large amount of water had escaped into the Tensas through breaks in Arkansas and North Louisiana, and I knew that a portion of this w would return to the Mississippi at the mouth of Red River, and would be superpo upon the Yazoo flood-wave, and I felt sure that it would give a flood of extraordin height. I met the president of the police jury at Pointe Coupée and went with to inspect the levees in the parish. I found some work in progress there under direction. He, as well as the people generally, seemed to be under the impres that the United States had taken charge of all the levees on the river and that th had nothing more to do. This impression gave me no little trouble to remove. Pe seemed to think that the danger was all over and were unwilling to leave their ho to work on the levees even when paid to do so. This unfortunate apathy caused loss of much valuable time. When the second rise in the river made itself mani the people again became alarmed, and after that I had but little trouble in procuring the labor that was necessary. The people as a rule then worked very hard and w ready and anxious to carry out my instructions. I was rather surprised to find that little was known among them as to the proper method of protecting levees, and number of cases I found them doing work which if not positively injurious did litt no good. The great trouble with the Pointe Coupée system of levees was that they w too low from Smithland to Point Manoir, a distance of about 40 miles. The lev were nearly all low, and there is scarcely a mile in the whole distance upon whi was not necessary to do more or less work.

In order to properly protect the levees on the Mississippi River in the northern p of Pointe Coupee Parish, it was necessary to extend the protection through to Atchafalaya and down this river on its left bank as far as the levees were good. breaks in the Atchafalaya system of levees would allow the backwater to come agai the Mississippi line, and in this way would cut off the supply of earth for repair them. The backwater would also weaken them by saturating their bases. I ther fore furnished some labor and material for this purpose. The material supplied use in the Atchafalaya was 12,300 feet of lumber and 7,200 sacks, and labor to amount of $506.87 was paid for. A great deal of additional labor was furnished the planters who were interested in holding this line. The work was not succes Before the flood had reached its extreme height numerous breaks had occurred in Atchafalaya levees below Simmesport, and the backwater caused no little trouble the Mississippi line above Morganza. From Barbre's, at the head of the Atchafal

and along Old River to Smithland, a distance of about 9 miles, the levee was generally good. It had been built in part by the United States; some labor, however, was necessary to repair leaks, sloughing places, and to raise it where it was low. Four thousand sacks and about 3,000 feet of lumber were furnished by the United States for this purpose, and $351.69 was paid for labor. The work was directed by Mr. J. Torras for the United States.

From Smithland to Raccourci Landing, a distance of about 13 miles by the levee, the line is a long distance back from the river, as it passes around to the westward of Raccourci, Old River. This levee had been built in part by the United States and the remainder by the local authorities. It had been raised recently by the State and was generally high enough, but it developed a good many bad places during high water, and a good deal of work was done on it by the planters. The United States furnished for the protection of this levee 1,000 sacks and paid $400 for labor. From Raccourci to Morganza, a distance of about 5 miles, the levee was very high and very much exposed, being near the river bank. A great deal of work was necessary upon this portion of the line; most of it had to be raised, and very many leaking and sloughing places developed in the levee, due to the fact that its slopes were too steep for the material of which it was constructed. Work on this portion of the line was under the immediate charge of Mr. Bourgeois. Fourteen thousand nine hundred sacks, 18,520 feet of lumber, and 150 pounds of nails were furnished by the United States for this work, and $1,601.13 was paid for labor. Tools were also loaned by the United States. The line was successfully held, but it required the utmost efforts of those in charge of it, who worked incessantly day and night during the storm. The Morganza Levee, which was 8,000 feet in length, as before stated, was of good profile, but of insufficient height, and built of sand, which leaked very badly. When the water was near the crown of the levee a walking-stick could be thrust into the bank with very slight pressure and water would come through the hole. One great trouble at this levee was due to the fact that the public road passed behind it, and when the road became muddy people traveled on the top of the levee, and the large number of animals that passed over it injured the rear slope and increased the difficulty of maintaining it. When specially bad leaks appeared earth was dumped into the river upon the slope, until the width of the crown of the levee was sometimes increased as much as 30 feet. This always had the desired effect, but it was very expensive, because the earth had to be brought in wheelbarrows, and the runs were necessarily very long. As the river rose it became necessary to raise the whole 8,000 feet of levee from 1 to 2 feet. Fourteen thousand six hundred sacks, 71,600 feet of lumber, 2,000 yards of cotton bagging were used on this work, and $6,364.15 was paid for labor.

Below Morganza is situated the Grand Levee, a very fine structure, built by the State. It was a little over a mile in length. It was constructed of good material and gave no trouble during the flood, except that it lacked height. It was necessary to raise it about a foot for its entire length. Four thousand three hundred sacks, 12,000 feet of lumber, and 250 pounds of nails were furnished by the United States for this purpose. Four hundred and ten dollars and thirteen cents was paid for labor. In addition to the work done in this portion of the line by the United States a good deal of work was done by a volunteer force that came on the steam-boat *Wheelock*, I understand, from the country about Grosse Tête. No break occurred in this line. From lower end of Grand Levee to the Scott Levee, a distance of about 6 miles, the line was generally low and generally bad. Portions of it had been recently raised by the State, but the new earth was not well sodded, and much of it was washed away by the waves. It was necessary to secure all this by a plank revetment, and to raise the other portions of the levee from 1 to 2 feet. For this purpose the United States furnished 21,300 sacks, 51,025 feet of lumber, 575 pounds of nails, and loaned a large number of tools. The United States also paid for labor to the extent of $1,262.82. A good deal of work along this line was done by the planters, for which, I understand, they were re-imbursed by the parish. The Scott Levee, about 1½ miles in length, was a very fine piece of work, and was built by the United States. It was of good material, but it lacked height to withstand the flood. It was necessary to raise it along its entire length. Near the lower end of it for a distance of 500 or 600 feet it crossed the bed of an old slough. It had given a great deal of trouble while it was being built by settling, and the settling has never entirely ceased. It was particularly low at this point, and a good many leaks developed here. They were all controlled, however, and the levee was saved. Seven hundred and fifty sacks, 11,900 feet of lumber, and 20 pounds of nails were used on this line, and $1,571.77 was paid for labor. Below this levee for about a mile to the St. Francis Church there was a double line of levee, as at Point Manoir. Upon my advice the president of the police jury admitted the water into this basin gradually and in time to save the back levee, although the back levee developed a bad leak, which required a day and night of very hard work to control. From St. Francis Church to Grand Baie levees, a distance of about 8 miles, the levee was generally very low and very bad. With the exception of two large dikes at Waterloo it was a small bank, the natural ground being very high,

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and it would not average over 5 or 6 feet in height, It was all too low, and had be raised throughout its entire length from 1 to 2 feet. For this purpose the Un States furnished 34,650 sacks, 37,345 feet of lumber, and 225 pounds of nails. T were loaned for this work. The United States paid for labor $2,553 and the par also contributed a certain amount. This line was breached, as has been stated three places, which breaks have since been closed. The Waterloo dikes were near 30 feet in height across the upper end of Fausse River. These dikes developed s of weakness during the flood, becoming very soft and muddy near the base of land slope, where it was very difficult to strengthen them. The method adopted e sisted in building a retaining-wall of sand-bags across the slough inside of the and at a proper distance from the toe of the slope, and filling in between this w earth in such a way as to re-enforce the bank by a heavy banquette. The result of t work was successful and the dikes were held.

From the Nina plantation to Point Manoir, a distance of about 2 miles, was nated the Grand Baie Levee. This had all the defects that a levee could have. was low, it was exposed in places to wave-wash, it was built of poor mater and it had been perforated by crayfish holes, overgrown by bushes, and pierced the roots of trees that grew on the batture or in its river slope. It gave trouble fr the time the water came against it, and a good deal of work had been done upo by the planters or the parish before the United States took charge of it. It was nec sary to raise it, to strengthen it, and to resort to a great many devices to stop le A line of light sheet-piling was tried to cut off crayfish-holes; it succeeded in s cases, but could not be generally used on account of the bushes and trees on the ri slope. This line was held, but it required constant watching and labor. The Un States furnished 5,000 sacks, 25,554 feet of lumber, and 250 pounds of nails for work, and paid $1,059.45 for labor.

The Point Manoir Levee has been fully described elsewhere. The work done u it by the United States consisted in raising it and stopping leaks: 2,000 sacks, 5, feet of lumber, 100 pounds of nails were used on this work and $868.65 was paid labor. This levee was broken and partially destroyed. From Point Manoir to P Allen, a distance of about 22 miles, the levees were situated in West Baton Ro Parish. They were generally well cared for, were in good condition, and but l assistance was required from the United States. Six thousand sacks were furnish to the president of the police jury for use at such points on this line as he thou necessary. They were distributed by him, the greater part of them going to Po Manoir. One thousand sacks were put off at Brusley Landing below Baton Rouge a were used at this place. From Baton Rouge to New Orleans the levees were in much better condition than in Point Coupee. Moreover, there was a line of railro on each side of the river and these roads had a vital interest in maintaining the lin They furnished a very large amount of material for levee protection to the plante along the line, and I understand that they furnished labor wherever it was necess to prevent a break or to strengthen the levees. For this reason no work was necess by the United States here. Four thousand sacks, however, were delivered to t president of the police jury of Iberville Parish at Plaquemine for use in this vicini The only breaks which occurred in the levees between Baton Rouge and New Orlea were the Martinez Crevasse, which was since closed, and the Nita Crevasse. Be the city the levees were generally small and they protected, as a rule, only a narr strip of country. As in the case of the levees above New Orleans, there was a l of railroad on each side of the river which was directly interested in maintaini the line. No assistance was asked from the United States for these levees exc where crevasses occurred, and aid was then furnished to close them. The price ge erally paid for labor was 10 cents an hour, but on Morganza, where a trained force levee builders was employed, the price was 15 cents an hour.

In addition to the work that was done below the mouth of Red River, abou $21,000 was expended for labor for a similar purpose on the Tensas Front, and su $7,000 worth of levee material was used here. For a full description of the kind an quantity of work done, I would refer to the report of Assistant Engineer H. S. Dou las, who was in local charge of this portion of the line.

My experience in protecting levees during this exceptionally high water has l me to think that the levees might be made more secure with but little increase in th total cost. The levees around the head of the bends are very much more exposed wave action than those along the sides of the straight ridges. The former mig well be made exceptionally strong at the expense of the latter. They ought to given 2 or 3 feet additional height to make them secure against the action of t waves. Where levees are constructed of sand, which should be avoided if possibl a flatter slope than 1 on 3 is necessary to make them safe. Where levees are built a foundation of doubtful character it ought to be fully explored. A muck-ditch muc wider and deeper than the standard one should be adopted and used, and if logs or rack heaps are discovered under the base of the levee they should be removed for at least half the width of the base. Good drainage on the land side of the levee is a

matter of very great importance. No water should be allowed to come against the base of the levee on this side. This point alone often will be sufficient to determine whether a doubtful levee can be held or not. In the sugar parishes, where the line is well drained, the levees, though actually of weaker profile than they are above, were in much better condition this year throughout the period of high water. No trees or bushes should be suffered to grow upon the levees. The best covering they can have is a good sod of Bermuda grass. The use of the levee as a public road is objectionable unless it is given a width of crown of not less than 20 feet, and proper care taken to maintain its height by adding earth from time to time as it is worn away by travel. Ramps should be provided at intervals so that it may not be necessary to ride or drive on the slopes. There is no objection to allowing cattle and sheep to graze on the levees while the water is low, for this improves the sod and keeps down the weeds, but they should all be carefully excluded from the levees from the time the water rises to its base. Cuts in the levees for roadways for flumes, or for pipes are all serious sources of danger, and they should not be permitted under any circumstances. As in the case of all similar works, the levees could be kept in much better condition than they now are by some regular system of annual repairs. To wholly neglect them till the time of high water comes, causes necessary work to be done in the most expensive and least durable manner.

CREVASSES.

The following is a condensed account of the crevasses that occurred in the Mississippi River below Vicksburg during the flood of 1890. The crevasses are described in the order in which they are situated on the river from Vicksburg down, and not according to the dates upon which they happened.

The Lake Concordia Break.—This crevasse is in Lake Concordia at its western extremity. It occurred on the 22d of April at about 10 o'clock a. m. It was at a point where the levee was about 6 feet high, and at this time the water was about 1 foot below the crown. The levee had shown no special signs of weakness, but it was of insufficient profile, and was subjected to a head of water greater than it was designed to resist. It is said that a stream of water burst through the embankment about half way up the slope, then the crown of the levee fell in, and in a short time the break was 50 feet wide. On the morning of the 23d it was 200 feet wide "with a very swift current washing through it and tearing its channel all to pieces." On the 10th of May it was 837 feet wide, with a mean depth of 13.35 feet, an average velocity of 4.21, and a discharge of 47,042 cubic feet per second. An effort was made to secure the ends of the levee by driving piles. It succeeded at one end of the crevasse and failed on the other.

Arnauldia.—This break is about 1 mile below the town of Vidalia. It occurred on April 23. It was due to wave wash, and it is thought that it might have been prevented if there had been a force to look after it, but the people were alarmed by the Concordia Crevasse, and were all engaged in saving their property, and no labor was to be had. The break on May 11 was 455 feet wide, 2.42 feet deep, and was discharging 1,871 cubic feet a second.

Henderson-Ashley.—The crevasse, like the others described, is in a levee on the right bank of the river, and is situated about 12 miles below Natchez. It was caused by the water running over the top of the levee. Like the preceding one it might have been prevented if there could have been a sufficient force to guard it. It occurred on April 23. It enlarged very rapidly to a width of 400 feet. On May 3 it was 700 feet wide and on May 12 it was measured with the following results: Width, 873 feet; mean depth, 7.77 feet; velocity, 5; discharge, 33,916 cubic feet a second.

These were all the crevasses that took place in my district, above the mouth of Red River. For a more detailed account of them, as well as for a description of the mode of measuring them, I would refer to the report of Assistant Engineer H. S. Douglas upon this subject, which is transmitted herewith.

CREVASSES BELOW THE MOUTH OF RED RIVER.

Raccourci Break.—This crevasse is situated in the line of levee that crosses Brunette Point, extending from Raccourci Landing to the bend of Old River. The break was on the plantation of Mr. Horace LeDoux. The levee was an old one, having been built in 1866, and was of a very weak profile. The levee was a leaky one, and had given trouble in former high waters. The crevasse occurred at 9 p. m., April 23. It is said that without previous warning a stream of water as large as a flour barrel burst from the ground at the toe of the land slope of the levee, and in a few minutes later the crown fell in, and the crevasse enlarged very rapidly. Three days later the break was 342 feet wide, 6 feet deep, and discharging 13,500 feet per second. On May 22 it was again measured, with the following results: Width, 380 feet; depth, 3.30

feet; mean velocity, 4.32; discharge, 5,417 cubic feet a second. There had been a fall at this point of 4.4 feet from the highest water. This office having furnished the necessary material, the work of closing this crevasse was begun by the planters May 23. The crevasse was completely closed May 28.

The following is a statement of labor and material used for this purpose:

Sacks, 10,000 delivered	$516
Lumber, 24,000 feet delivered	3[illegible]
Nails, 4 kegs at $3.50	14
Labor, 309 days, at $1	30[illegible]
Total	1,21[illegible]

There was a small amount of material left over, but that has not yet been returned. The total length of the structure built to close the break was 450 feet. The greatest depth of water through which it was carried was 4½ feet and the average depth in front after the break was closed was 3½ feet. The work of course could not have been done for anything like the above sum if it had been undertaken when the flood was at its height. The crevasse was closed according to a plan prepared by me, a which will be hereafter described.

Upper Morganza.—This levee at the point where the break occurred is situated a distance of at least a quarter of a mile back from the river bank and is concealed from view from the river by a heavy growth of cottonwoods. The levee was of good material and well sodded, but it lacked height and it had been raised with sacks and earth on an average 1.1 feet, though at some places the raising amounted to a great deal more than this. The break took place during the night of April 22, near midnight. The storm at this time was very severe and the waves were driven by the southeasterly gale against the levee with great violence. The water was almost on a level with the top of the sacks, and every wave broke over them. As the storm increased the waves began to move the sacks themselves. For a time the guards were able to replace and secure them, but finally a breach was made nearly 50 feet wide through the line of sacks; the water poured over the levee, which was about 14 feet high; the men were driven from their work, and in a short time the levee was cut through and the crevasse was formed. When I visited the break at 8 o'clock the next morning it was about 400 feet wide and appeared to be discharging about 50,000 cubic feet a second. It was a very angry looking break. The swamp had not yet filled with water and there was a fall of several feet right in the throat of the crevasse. The water dashed in among the trees, which were trembling and falling, and the noise of the rushing water could be heard for more than a mile. Four days later, when the swamp had been filled by this and other crevasses and the river had been lowered at this point some 3 or 4 feet, the break was 650 feet wide and the discharge reduced to 40,320 feet per second. On the 22d of May, the crevasse was 1,000 feet wide, 8 feet deep, with a mean velocity of 5 feet and a discharge of 31,600 cubic feet per second. The level of the water at the crevasse was not less than 7 feet below what it was when the levee broke. The levee was not the one which was reconstructed by the Mississippi River Commission.

The Morganza.—This levee was built by the Mississippi River Commission and the State of Louisiana jointly during the winter of 1886–'87. It was about 8,000 feet in length, and was constructed with the utmost care, and was a very good structure of its kind. The only faults with it were these, that it was built of river sand, which washes very easily when the sod is once broken, and which does not make a perfectly tight bank, and also that it was not of the proper height. It was given a height of a foot and a half above the high water of 1882. But this flood wave would have been locally depressed here because the crevasse was then open, besides the levee had settled somewhat and in many places was below net grade. In building the levee great care was taken to secure a perfect bond between the bank and the natural surface of the ground. In places where stumps and buried drift-logs were found the muck-ditch was made as much as 14 feet wide, and all foreign material was removed. The levee was very finely sodded, and its slopes were as smooth and true as those of a fortification. The levee had been raised during the high water from 1 to 2 feet along its entire length, and this work was the best of the kind that was done anywhere in my district. The new earth was protected by boards nailed to pickets driven in the crown of the levee near its exterior crest, and inside of the board a breadth of cotton bagging was placed to keep the earth from washing under or through the revetment. On all exposed portions of the levee the new earth was 6 feet thick and was retained on the land side by boards secured as in front.

The break occurred on the night of April 22. The cause of it can never be absolutely determined. The storm on this night was fearful, and the waves in the river running very high. There was nobody on the levee at the time that it broke. The guards, who were all people living in the vicinity, had become demoralized by the

that had occurred the night before, and had all left the work to try to save tock and other property from the overflow. I had examined the levee on the d found that the effect of the upper break, which was only about 300 feet from nza, had been to lower the water to about the level of the crown, and it seemed that the levee was safe unless the upper break should extend downward far h to involve it.

ing the night of the 22d the storm came from the east, and had a clear sweep up the river from Bayou Sara to Morganza, a distance of about 12 miles. The of this must have been to back the water up in the head of the bend, and its e must have been elevated by this cause several inches at least. At Bayou know, for I was there that night, the water was 4½ inches higher for a short during the night than it was in the evening or the morning when the gauge ead. I believe that during the storm the water rose again above the top of the levee, and that the force of the waves was sufficient to wash out the sand from d the revetment, and thus permitted a flow over the top of the levee which d away as soon as the sod was broken. In fact, a place has been found on what ins of the levee where this very thing had taken place, and the water had actually n to cut a channel in the crown, but had been stopped by the fall in the river, due other crevasse. The people living in the vicinity believe that the levee was cut, think that the explanation that I have given is the true one. I visited the cre- on the 23d at 4 p. m. At this time the opening was about 600 feet wide, and I esti- d the discharge at 90,000 cubic feet a second. On the 25th at 10 a. m. I visited the asse and found it 1,227 feet wide, with a discharge of about 117,800 cubic feet. The up behind the levee was filling up and the current was greatly reduced, and it ed more like a river than a crevasse. The levee was washing away on the south end e rate of about 300 feet in twenty-four hours. As it had cost at the rate of about o the running foot the loss was very serious. As I expected this would be so, I e preparations to protect the end by a willow mattress as soon as the break rred. I telegraphed for a barge-load of rock from New Orleans on the afternoon e 23d, and on the afternoon of the 25th it arrived at the levee. In the mean time d a force engaged in cutting willows, and on the 1st of May the mattress was pleted and sunk on the river slope of the levee about 60 feet from the break. The tress was built of fascines each 50 feet long and 1 foot in diameter; they were ed together side by side with heavy rope so as to form a mat that was 50 by 125 . Thus built it was very stiff crosswise and very flexible lengthwise, so that n in place it could wrap around the levee but could not slip down off the slope or ble up if not well supported. To sink it rock was placed in double sacks and tied he rope lashing in such a way that it could not slide off when the mat assumed an ined position on the slope of the levee. The levee soon caved up to the mat after as placed and, as was expected, the mat wrapped around the end and protected erfectly. As the construction of the mat was novel I send herewith a drawing which it can readily be understood. When the mat was placed on May 1 the k was 2,180 feet wide. It was measured on May 22 and it was 2,543 feet wide, wing that there had been a loss of bank of 360 feet between these dates. Part of took place where the mat was, in order to permit it to adjust itself around the of the levee. The loss here was perhaps 120 feet, as the mat was placed 60 feet the break, and the rest, about 240 feet, must have been lost from the north end. was not a very serious matter, however, being only about 10 or 12 feet a day. ould have been impossible to place a mat there under any circumstances, because part of the levee being between two crevasses was an island, and barges of rock willows could not have been taken to it owing to the strong currents. The mean th of this crevasse on May 22 was 13.117 feet, its mean velocity 4.373 feet per nd, and its discharge 146,034 cubic feet. The water-surface at this date was ut 6.6 feet below high water.

he Snead Crevasse.—This break is in a small levee of weak profile. It is about 3 s below Morganza on the same side of the river. It occurred on the night of il 21 at 9 p. m., and was due to the force of the waves and possibly to drift-logs en against the levee. Four days after the break it was 90 feet wide and discharg- about 2,000 cubic feet per second. The break ceased to enlarge ten days after it pened. Its width May 22 was 147 feet; mean depth, 3.56 feet; velocity, 6 feet; harge, 3,139 cubic feet. This crevasse could easily be closed, but no one seems ious to undertake it.

he Lanaux Crevasse.—This break is about 500 feet below the one just described. appened about the same time, and was due to the same cause. Four days after break it was 110 feet wide and was discharging about 2,640 cubic feet. It ceased widen in about ten days. On May 22 its width was 151 feet; mean depth, 3.36; an velocity 6 feet, and discharge 3,044 cubic feet. The water-surface at both of se breaks was at this time about 5 feet below flood height. Like the former this ak could readily be closed.

he Fanny Riche Crevasse.—This crevasse occurred in an old levee about 2½ miles be-

low the one just described. The levee was situated very near the river bank, a was expected that it would cave into the river in a few years, and for this rea had not been raised at the time that the other levees in the vicinity were bei paired. It was, therefore, very low and of very weak profile. It had a width of about 18 inches on the crown, and during the flood it had been necessary to ra as much as 20 inches. This work was done by means of a plank revetment an backing of earth in sacks. At the time that the break occurred the water almost as high as the top of the new work. At about 9.30 a. m., April 21, a steam-boat passed up the river, and it is said that the swells from this boat lo and washed away some of the planks from the revetment; this allowed the wa attack the new earth, and before a sufficient force of laborers could be collected pair the damage the levee was breached and a crevasse was formed. When I sa break at 12.30 p. m. it was about 240 feet wide and it was discharging about cubic feet of water per second. It enlarged rapidly for the first ten days, after there was very little change in its condition. On the 22d day of May it was ured with the following results: Width, 845 feet; mean depth, 7.37 feet; av velocity of discharge, 4.35 feet per second, and the discharge at this time was cubic feet per second. It has been proposed to close this crevasse and some planters living in this vicinity applied to me for aid. But inasmuch as the ba was only about 35 feet wide, and as the depth of the crevasse at the north end distance of 225 feet averaged about 11½ feet and the velocity in this section nearly 6 feet, I felt that it would be a very difficult and expensive operation to the break at the present stage of the river, and I did not feel authorized to fur any assistance.

The Preston Crevasse.—This break is situated in the levee nearly opposite B Sara, and like the one just described the levee was an old one and was too low. had been raised during the flood by a double tier of sacks, and at the time the b occurred the water was running over the sacks in places. The break occurred a midnight of April 21; it was doubtless due to some of the sacks being washed o levee by the force of the waves. The break widened rapidly and soon attai width of 200 feet with a discharge of about 10,000 cubic feet per second. As the fell it became evident that the crevasse could be closed, and accordingly work commenced on the 12th of May under the direction of Mr. Bennett Barrow, and was pleted May 17, at which time the flow of water was completely stopped. The ma used for the closure of this break was furnished by the United States, and the I understand, was paid for with money furnished by the Louisiana Lottery Comp The method of closing was the same as that used at the Raccoureci break, and w will be hereafter fully described. The material furnished by the United States sisted of 40,000 feet of lumber, 20,000 sacks, and 4 kegs of spikes, the whole va at $2,400, and I was informed that the labor account amounted to a little over $1 making the total cost of closing the crevasse a little less than $4,000. The length of the structure, built to close the crevasse, was 660 feet; the greatest d of water along the line upon which the break was closed was about 8 feet an average depth about 4 feet. In the throat of the crevasse, after the break was cl there was found a depth of water as great as 45 feet and the average depth was siderably over 30 feet. The width at the time of closing from end to end of the was 213 feet. About 3,000 feet below this break are two other small breaks whic known as the Taylor crevasses. The lower one of these occurred first. The c tion of the levee was the same as the one already described, if anything it w little lower and the raised work of course was higher. The first break occurre the morning of the 21st of April. At the time that I saw it, about 10 a. m., it about 50 feet in width and was discharging about 3,000 cubic feet of water per se The other break, which was about 600 feet north of No. 1, was about 40 feet in w and occurred later in the day. Both these crevasses were closed by Mr. Barro the same time that he closed the Preston break. The first one was closed by a l inch boards used as a sheet-piling and re-enforced with sacks filled with earth. T had been no wash below the base of the levee, and this line was driven right foot of the river slope. The width of the break at the time of closure was 203 No. 2 was closed at the same time as No. 1 and in a similar manner. Its width then 51 feet. As there was very little water flowing through these breaks at the they were closed, no special account was kept of the cost of closing them; it amou to but little and is included in the cost of closing the Preston break. This comp the list of crevasses which occurred in Pointe Coupée Parish; the next two ar West Baton Rouge on the right bank of the Mississippi River.

The first of these is the *Point Manoir Crevasse.* The conditions here were peculiar, and it certainly seems that this break was a preventable one. At this there was a double line of levee; the front levee was a very old one, of strong pr and well constructed, although it lacked height; but it was situated along the ca portions of the river, and it was thought that it would ultimately be destroyed b caving of the bank. For this reason the State, during the winter of 1886–'87, built

s known as the New Point Manoir Levee, extending down the river a distance of bout a mile, where it is connected with the old levee. The old and new levees thus nclose a rectangular space about 850 feet wide by 5,000 feet long. For some reason or ther the front levee had never been cut so as to permit the water to come against the ew levee. At the time I saw it, about March 20, the water was standing about a foot elow the crown of the old levee. The current of the river was setting in very trongly in the bend, and it seemed to me that there was great danger that the front evee would cave into the river. If it did this, I felt quite sure that the rush of water gainst the new levee would break it and in this way a crevasse would be formed at a place which ought to be doubly safe. These works were not United States levees, nd as the ground between the two lines was occupied and under cultivation, I did ot feel authorized in overflowing it without the consent of the owners. They de-lined to consent, and accordingly I visited the president of the police jury of West Baton Rouge and urged him to fill the space between the two levees by means of a iphon or a box-flume, which could be controlled. I advised him to fill the space at he rate of 6 or 8 inches a day, so as to give the new levee time to consolidate, and to e prepared, in case the new levee showed signs of weakness, to shut off the supply of water and hold the front levee until the new line could be repaired and strengthened. He promised to do this, but the work was done so slowly and so frequently delayed from causes which it is not necessary to mention here that at the end of April the basin was only partially filled. At about midnight on the 30th of April the front levee caved into the river near the upper end. The rush of water caused the opening to enlarge until it had attained a width of 600 feet. This large flow of water so suddenly precipitated upon the back levee caused it to give way, and a breach was formed in it within a few hours after the first levee broke. The width of the break in the new levee became finally equal to 571 feet. In six days, however, after the break occurred its width was only about 300 feet, its mean depth about 4 feet, and its discharge 12,000 cubic feet per second. This break was closed by the parish authorities on the 17th of May. Work was commenced on the 9th. The method used consisted in driving the line of sheet-piling from opposite sides of the break along a curved line on the inside of the levee. As the lines of sheet-piling approached each other the force of the current became so great that they were obliged to use a crib structure similar to that used at the Preston and Raccourci breaks. The entire crevasse could have been closed by this latter method in much less time and at a much less expense. The length of the structure used to close it was 980 feet, the average depth of water along the line on May 23 was 2.82 feet; the water in the river at this time was 4.82 feet below high water.

The next break was the *Lobdell Crevasse.* This occurred in a levee on the west bank of the Mississippi, opposite the western extremity of Profit Island. It occurred at about 4.30 p. m., April 22. The levee was a large and high one, standing about 1.7 feet above the highest water of this year. It had a wide crown and good, full slopes, and the entire levee is well sodded with Bermuda grass. It is said that the water burst out of the ground immediately at the foot of the land slope in a large stream, as big as a flour barrel, and in a few seconds the top of the levee collapsed and the crevasse was formed. The break enlarged rapidly, the caving being mainly at the north end. On the 26th of April it was 956 feet wide, 6 feet deep, with a discharge of 57,300 cubic feet per second. The water from this break overflowed a very fine and highly cultivated tract of country, and the people were very anxious to attempt to close the break. They desired to close it by means of a patent sheet-piling, a method in which I had no confidence. I, however, furnished them about 15,000 sacks to use in closing the break. They continued to work upon it for about a week, but the rapid current scoured out the piles and the work was finally abandoned. On the 3d of May the crevasse was measured, with the following results: Width, 1,981 feet; mean depth, 7.22 feet; average velocity, 4.12 feet; discharge, 58,892 cubic feet per second. The river at this time was 5.8 feet below the flood height. On the 23d of May a second attempt was made at the north end of the break to close a deep channel by the sheet-piling process, in a hope that a part of the discharge through the crevasse could thus be shut off and the injury that it was causing proportionately reduced. No report of this work has yet been received, but it is understood that it was not successful or that it did not accomplish the purpose.

The next break was the *Martinez Crevasse.* This was situated on the left bank of the river, about 8 miles below Baton Rouge. It occurred on the night of April 22, during the storm; it is said to have been due to the existence of a rice flume. The water was very near the top of the levee at the time the break took place. Twenty-four hours after the break occurred it attained its maximum width, which was 124 feet. I estimated the discharge through it at 4,800 cubic feet per second. This break threatened to inflict very great damage on a large portion of country which hitherto had been safe. It was feared that the water from it would join with the water from the Nita Crevasse and thus overflow the entire valley on the left bank of the river from Baton Rouge to New Orleans. Immediate effort was made to

close the crevasse. The Mississippi Valley Railroad and the planters living in vicinity contributed labor and material. The work was done under the immed direction of Mr. James D. Houston, a planter living in the vicinity. The work fairly started April 24 and was completed April 28. The length of line upon w the closure was made was about 500 feet; the style of work was similar to tha the Preston break, but the structure was not very skillfully designed, and the m rial was not all used to the best advantage. There was an excessive strength some portions of it and in others it was hardly strong enough. The distance betw the levees and the river bank was not very great, and as a result the crevasse ch nel extended nearly to the bank before the break was closed. The depth in the th of the crevasse was about 42 feet. On the inside of the line of cribbing it va from 6 feet to 20 feet. The cost of closing this break was very great. The railr company contributed about $13,000 in labor and material, the Mississippi R Commission about $5,800 in material and service of steam-boat, and the plan contributed a very large quantity of labor, more than was necessary, in fact, of w no account was kept. The closure of the break, however, was worth all that it

For a more detailed account of the breaks from Red River down I would refe the report of Assistant Engineer W. J. Hardee, which is transmitted herewith.

The next break was the *Nita Crevasse*. This is situated on the left bank of Mississippi River, about 5 miles above College Point. The break occurred on night of March 14. It is said to have been due to the existence of a rice flume in levee. It enlarged very rapidly in spite of every effort to control it, and on the of March it had attained a width of 642 feet, an average depth of 14 feet, a m velocity of nearly 10 feet, and a discharge of about 90,000 cubic feet per second was believed at this time by the managers of the Mississippi Valley Railroad that break could be closed. The injury that it inflicted upon them was very great, for line of their railroad was only a few thousand feet from the levee, and the track completely cut in two by the crevasse, and their business with the city of New Orl was completely interrupted. They proposed to cross the break on the line of levee by a strong timber trestle-work, and to make use of this structure as a br from which to close the break. If such a structure could have been put across crevasse it is probable that the break could have been closed, but great difficulty experienced in handling the long piles which it was necessary to use when the tr got out into the swift current. About 75 feet of trestle-work was carried out i the north end, but in the mean time it was found impossible to secure the south and the trestle-work was abandoned. The crevasse continued to enlarge in spite the efforts to control it. In the latter part of April an attempt was made to pla mattress on the end of the levee similar to the one used on the Morganza break. at this time the river had fallen somewhat in the vicinity and the base of the le was nearly out of the water, and the crevasse seemed rather to be in the bank its than in the levee. The mattress constructed was a very fine one of its kind. It 42 feet wide and 112 feet long. It was built under the direction of Foreman Ve an employé of the Mississippi River Commission. The plant belonging to New leans Harbor was used for this purpose. The mat was dropped at the south en the break, but it was not large enough to afford the necessary protection, and it undermined and finally disappeared, and the crevasse continued to enlarge. A large amount of money was expended by the Mississippi Valley Railroad Compan attempting to close or to control this crevasse. The Mississippi River Commis contributed about $5,400 in labor, material, and service of boats for this same pose. On the 9th of May the crevasse was measured, and it then had a width of feet, a mean velocity of 9.28 feet, a mean depth of 15 feet, and a discharge of 40 cubic feet per second. This discharge seemed so great that by direction of the C mission I caused it to again be measured on the 21st of May. This time a cur meter was used and a line was taken at a considerable distance inside the bre The section was carefully sounded. The discharge thus determined was 356,985 feet a second. The gauge at College Point had in the mean time fallen about e tenths of a foot. This would reduce the discharge through the 2,892-foot opening less than 25,000 cubic feet per second. This quantity added to the measured charge gives 381,985 cubic feet, which checks pretty well for work of this kind.

These are all the crevasses which occurred above the city of New Orleans. Be the city there were a great many small breaks, most of which, however, have been cl The Myrtle Grove, however, is still open. It is situated in the right bank of the M sissippi River, 35 miles below New Orleans. There are really two breaks at t point. They occurred during the morning of April 21, and were about 300 feet ap All enlargement ceased four days after the breaks happened. The original le was 5½ feet high. At the time the breaks occurred the water was very near the top of the levee. The crevasses were due to sloughing. On the 9th of May crevasses were measured with the following result: No. 1, width, 295 feet; velo about 5 feet; mean depth, 3½ feet; discharge, 5,150 cubic feet per second. N width, 540 feet; velocity, 2.15 feet per second; mean depth, 5½ feet; discharge,

ıbic feet per second. No effort has yet been made to close these breaks, but I have ›tained some material that was left over from closing other breaks in this vicinity, › be used at Myrtle Grove in case it is desired.

Besides those breaks already described there are a large number of others below the ity, a description of which has been furnished by Mr. H. S. Bell, secretary of the ew Orleans and Gulf Railroad Company, as follows:

"No. 1. February 13, crevasse occurred at St. Sophie, about 35 miles below New rleans. Break about 75 feet wide, and closed on February 15.

"The levee was about 5 feet high on side next the public road, and 3 feet high n batture side. This levee was a very old one, and a new levee had been built on the atture between the old levee and the river. The new levee was built entirely of and, and when the high water came against it it melted away, and left the protec- ion of the plantation entirely to the old levee, which was in a very bad condition nd full of cray-fish holes, and requiring constant attention and patching up. Imme- iate cause of this break was supposed to have been cray-fish holes. The break was losed by crib-work in the shape of a horseshoe, on the river side of the levee. The ribs were driven down in a double row of boxes about 4 feet square, and filled in vith sacks of earth as fast as the cribs were down. The crib-work was braced rom the outside, and afterward sacks and loose earth were filled in on the river side, naking a comparatively dry levee.

"No. 2. February 13, a crevasse occurred as Corinne, about 8 miles below New)rleans. This break was closed on February 15. The levee at Corinne was about 5 eet high. Cause of crevasse, cray-fish holes. Break was closed by crib-work, built traight across, joining the two ends of the levee, and filled in with straw and sacks f earth well braced on the outside. The crevasse was 25 feet wide.

"No. 3. February 23, at Bertrandville, three breaks occurred; one on Brulard's lace, and two at Pierre Bertrand's place. These breaks were from 10 to 15 feet wide.

"The levee in this neighborhood is about 4 feet high. One of the breaks was aused by an old rice flume being forced out, and the other two breaks by drift logs riven by the wind against the levee. Work was commenced on these breaks im- ediately, and they were closed the same day by crib-work, filled in with sacks of arth, in the direct line of the levee.

"No. 4. February 24, crevasse occurred at New Texas Landing, about 55 miles elow New Orleans. This break was reported to be about 30 feet wide, and was losed on February 28. Do not know the height of this levee, the cause of the revasse, nor how it was closed.

"No. 5. March 4, a crevasse occurred at St. Sophie, about 35 miles below New)rleans. Crevasse was 30 feet wide, and closed on March 10. Immediate cause of his crevasse was cray-fish holes near an old rice flume, which was washed out in a ery short time, and the increased depth of water through the rice flume caused a reat deal of trouble in stopping this crevasse. Closed the crevasse by a lengthy V- haped crib-work on the river side of the levee. The levee in this neighborhood was bout 5 feet high.

"March 7, a small break, about 15 feet wide, occurred in the levee at St. Sophie, bout 300 yards from the crevasse of the 4th instant. This break was closed on the th instant by a straight crib-work in a direct line of the levee. Caused by cray-fish oles.

"No. 6. March 14, a small break occurred at Empire Mills, 47 miles below New)rleans. The crevasse was about 15 feet wide, and closed on same day. Levees in his neighborhood from 4 to 5 feet high.

"No. 7. March 19, three breaks occurred in the Bohemia Levee, just below the erminus of the New Orleans and Gulf Railroad. Break from 30 to 50 feet wide. here is an immense batture in front of the old levee at Bohemia, and a new levee ad been constructed between the old levee and river about 100 yards distant from he old levee. The new levee had not been fascined, and being built on the batture, rom river sand, was soon washed away by the force of the high water; and the old evee was completely honey-combed by cray-fish and fiddlers. These crevasses were losed on March 30. The levee at Bohemia is from 4 to 5 feet high on the road side nd 3 to 4 feet on the river side.

"No. 8. Mach 21, a crevasse occurred at Harlem, about 38 miles below New Orleans. he levee at this point is 8 feet high on the road side and 5 feet high on the river ide. Break was caused by an old rice flume giving way. It was closed on March 5 by a double row of cribbing, horseshoe-shaped, on the river side. Outside, below he cribbing, was filled with sacks of earth, and inside or river row of cribbing was lled with loose earth.

"No. 9. March 26, a small break about 10 feet wide occurred at Harlem. Work vas commenced on it immediately, and it was closed on the 27th by a straight row of ribbing in the direct line of the old levee. The cause of this was a cray-fish hole, vhich had been previously boxed up.

"No. 10. March 26, a small break, about 15 feet wide, occurred at Martin's, near

Empire Mills, about 47 miles below New Orleans. A cray-fish hole was the c of this crevasse. The levee was 5 feet high, and the break was closed on the s day by straight crib-work, joining the two ends of the levee.

"No. 11. March 26, two breaks at Corinne; one 30 and one 25 feet wide; close same day. Here the levee is about 5 feet high on the road side and 3 to 4 feet on the batture side. The break was closed by a V-shaped crib-work, filled with s and loose earth. The cause of this crevasse, cray-fish holes.

"No. 12. March 22, a small break at Woodland, about 10 feet wide, and close same day by straight crib-work, joining the two ends of the levee. Here the le are about 4 feet high. Cause of break unknown.

"No. 13. March 28, two small breaks occurred in the New Orleans and Gulf R road Levee, at Bohemia, about 50 miles below New Orleans. One of the breaks about 10 feet wide, and the other 6 feet; both were closed on the same day as n One of these breaks was caused by an alligator hole, and the other by a cray-fish The levees are about 5 feet high.

"No. 14. April 2. one of the crevasses at Bohemia, just below the terminus of New Orleans and Gulf Railroad, which had been closed on March 30, broke out a and is still open.

"No. 15. April 21, seven breaks occurred at St. Sophie and immediate vic Cause was the violent storm on that date. The levee at St. Sophie is about high, and all of the breaks were successfully closed on April 30. The United S Government furnished 60,000 feet of lumber, 20,000 sacks, and 12 kegs of spike closing these crevasses; of this lumber, 5,000 feet was delivered to Haspel & for closing another crevasse, and about 3,000 feet to T. S. Wilkinson for Myrtle G and there is still remaining at St. Sophie about 15,000 feet of this lumber u These breaks were closed by crib-work on the river side, either horse shoe-shap V-shaped, as usually found most expedient.

"No. 16. April 21, two small breaks occurred at Thibauts, 43 miles below Ne leans. Breaks 10 to 12 feet wide, and closed on April 26. These breaks are c by the severe storm of the 21st. The levee in this neighborhood is about 5 fe and the break was closed by a straight crib-work, in the direct line of the leve

"No. 17. May 10, a small crevasse occurred at Harlem, about 15 feet wi closed on May 10. It was caused by a cray-fish hole. Here the levee is about high. The break was closed by straight crib-work.

"There was very little work in the way of raising levees in the immediate vi of the breaks just enumerated. Several places levees on the lower coast, bet New Orleans and Bohemia, were raised, by piling up sacks filled with earth, in some cases the water raised to fully 1 foot above the crest of the old levee; bu was not the case at any of the levees at which breaks occurred. There w an instance of the crevasses being caused by the river washing over the leve cutting it away."

These were all upon the left bank of the river, and it will be seen that the all small and very quickly closed. On the right bank there was a break at Ric 51½ miles below the city of New Orleans. It was a small, low levee, and was a uted to the effect of waves. It occurred on the 19th of April, and attained w six days a width of about 100 feet and a discharge of about 4,500 cubic feet per se An attempt was made to close it about the 25th of April, and the work was fin a few days later. Labor was furnished by people living in the vicinity, an United States furnished material as follows: 46,790 feet of lumber, 3,000 sacks, of nails, and 25 pounds of twine of a total value of $547.43. No account has furnished of the amount of labor that was necessary to close the break. There also a break at Live Oak plantation, about 30 miles below New Orleans. This occurred about midnight of March 19. Its width was 116.7 feet, its mean d 6¼ feet, its average velocity 7¾ feet per second, and its discharge 5,881 cubic fe second. There was a heavy growth of willow on the batture in front of the le which tended to diminish the velocity of the discharge. The plantation behind levee was unoccupied, and the levee was not very closely watched. It is thought the break was due to injuries caused by the cray-fish or some other burrowing mals. The work of closing the crevasse was commenced soon after it occurred, it was finally closed on April 10, but even at this time there were some leak through the work. The United States Government furnished 93,000 feet of lu 20,000 sacks, and about 40 kegs of nails for this work. The New Orleans, Fort J son, and Grand Isle Railroad expended about $7,000 towards closing the break the Citizens' Bank of New Orleans, which owned land behind the levee, contr about $4,000 more, making the total cost of closing the break between $13,0 $14,000. In addition to these breaks on the Mississippi River there were a number of others on Bayou Des Glaise. There were also two breaks in Old Riv at Barbre's Landing, and the other about half-way from this point to the M sippi River. A list of these breaks, with the time that they occurred and the

with the amount of water escaping through them at the time they were measured, is given as follows:

Crevasses in Old River and Bayou des Glaise.

Name.	Date of break.	Cause of break.	Width of crevasse.	Depth in crevasse.	Velocity per second	Discharge.	Height of levee.	Amount raised.	High-water mark below top.	Present surface below top.	Material used in raising.
IN OLD RIVER.			*Feet.*	*Feet.*	*Feet.*	*Cu. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Ferguson	Apr. 22	Cray-fish.	153	6	0.5	459.0	4.5	.....	1.0	4.0	
Barbre	Apr. 21	....do	212	3.5	4.0	7,208.0	4.5	1.25	.....	3.7	
BAYOU DES GLAISE.											
No. 1	.....	Slough	598	4.6	4.8	13,203.8	6.8	.....	1.5	4.0	
No. 2	Apr. 21	Ran over	180	1.0	3.3	594.0	3.7	.....	*2.0	0.5	
No. 3	Apr. 21	....do	54	2.5	6.4	864.0	4.5	.....	*1.6	1.2	
No. 4	Apr. 12	....do	40	1.4	4.3	240.8	4.5	.....	*1.8	1.2	
No. 5	Apr. 10	....do	1,600	0.3	0.5	240.0	3.0	.....	*1.8	0.8	
No. 6	Apr. 21	....do	1,500	†1.7	.....	.....	.....	.....	.....	.....	
No. 7	Apr. 22	Cray-fish	175	5.0	1.8	1,415.0	3.0	1.0	.....	2.3	
No. 8	May 1	....do	70	2.0	2.2	308.0	3.0	1.2	0.1	2.4	
No. 9	Apr. 22	....do	102	1.0	1.5	153.0	4.5	2.3	0.2	2.6	Earth and sacks.
No. 10	Apr. 22	Ran over	435	†1.0	.....	.....	.....	.....	.....	.....	
No. 11	Apr. 22	....do	180	†1.8	.....	.....	.....	.....	.....	.....	
No. 12	Apr. 21	....do	60	1.1	1.3	85.8	3.0	1.5	0.2	2.6	Earth and boards.
No. 13	Apr. 21	....do	50	3.0	1.9	285.0	3.0	1.5	0.2	2.6	Do.
No. 14	Apr. 21	....do	195	2.3	1.5	672.7	4.3	2.0	.....	2.4	Do.
No. 15	Apr. 24	Slough	75	2.3	1.0	172.5	4.5	2.3	0.1	2.6	Do.
No. 16	Apr. 24	Ran over	60	2.0	0.9	108.0	4.0	0.5	.....	2.5	Do.
No. 17	Apr. 24	Slough	123	6.2	1.2	915.1	4.5	1.5	0.2	3.0	Earth.
No. 18	Apr. 24	Ran over	150	†2.0	.....	.....	.....	.....	.....	.....	
No. 19	Apr. 24	....do	418	†1.0	.....	.....	.....	.....	.....	.....	
Red Fish post-office.											
No. 20	Apr. 28	Slough	90	4.0	0.8	288.0	3.5	1.5	0.5	2.5	Sacks.
No. 21	Apr. 21	Ran over	760	0	0	.....	2.0	2.0	.....	2.0	New levee.
No. 22	Apr. 28	....do	850	0	0	.....	1.5	1.5	.....	1.2	Do.
Hamburgh.											
No. 23	Apr. 23	....do	(‡)	0.2	1.5	1,980.0	1.5	1.5	.....	1.2	Do.
No. 24	Apr. 28	... do	(§)	.....	.....	.....	.....	.....	.....	.....	
No. 25	Apr. 24	....do	2,100	0	0	.....	3.0	1.0	.....	2.8	Do.
No. 26	Apr. 22	Slough	50	5.5	0	.....	2.7	.....	0.2	3.0	Closed inside.
No. 27	Apr. 27	Ran over	60	0	0	.....	3.0	0.5	.....	3.0	Earth.
No. 28	Apr. 28	Slough	408	4.0	2.0	3,264.0	5.0	.....	0.5	3.5	
Old Church.											
No. 29	Apr. 22	Ran over	600	0	0	.....	3.5	0.5	.....	3.0	Earth and planks.
No. 30	Apr. 22	....do	200	5.5	1.3	1,908.0	4.0	2.9	0.5	3.5	Do.
No. 31	Apr. 22	Reported cut cray-fish.	564	4.0	2.0	4,512.0	6.5	....	2.0	5.0	
No. 32	Apr. 22	Cray-fish	700	4.0	2.7	7,560.0	4.5	0.5	0.5	2.5	Earth.
Big Bend											

* Above.
† When water was highest.
‡ 1¼ miles.
§ Ten miles; no levee; bank 1.2 feet above present level of water; ran over 1.3 feet deep at highest water; this and No. 23 and 25 ran back into bayou from crevasses above in Big Bend.

From No. 21, 2 miles below Hamburgh, on Bayou des Glaise, to No. 26, below Old Church, a distance of about 20 miles, there are practically no levees on the bayou. At Hamburgh a 2-foot levee was thrown up and held, keeping out the water; below a small ridge had been thrown up, but was washed away. In places above Ham-

burgh old levees exist, but for 10 miles out of 18 miles the banks are high and th are no levees. This entire unprotected front was overflowed from the rear. T breaks at Nos. 30, 31, and 32, at the lower end of Big Bend, filled the swamps and surplus then returned to the bayou over this unprotected front. No. 31 was repor as having been cut, but there was no proof.

Location and measurements of crevasses in the fourth district, Mississippi River, 189

Name.	Date of—		Width.	Depth.	Mean velocity per second.	Discharge per second.	Bank.	Location (below Cairo.)	Remarks.
	Break.	Measurement.							
			Feet.	*Feet.*	*Feet.*	*Cu. feet.*		*Miles.*	
Lake Concordia	Apr. 22	May 10	837	13.35	4.21	47,042	R.	(*)	
Arnauldia	Apr. 23	May 11	455	2.42	1.70	1,871	R.	701¼	
Henderson-Ashley	Apr. 23	May 12	873	7.77	5.00	33,916	R.	711¾	
Raccourci	Apr. 23	May 22	390	3.30	4.32	5,417	R.	(†)	Closed May 2
Upper Morganza	Apr. 21	May 23	790	8.00	5.00	31,600	R.	788½	
New Morganza	Apr. 22	May 22	2,543	13.117	4.378	146,034	R.	789½	
Sneed	Apr. 21	May 22	147	3.56	6.00	8,189	R.	792½	
Lansaux	Apr. 21	May 22	845	7.37	4.35	27,118	R.	792¾	
Preston	Apr. 21	May 23	213	4.60	.....	.....	R.	794¼	
Taylor No. 1	Apr. 20	May 23	203	3.40	.....	.....	R.	801¾	Closed May 7
Taylor No. 2	Apr. 20	May 23	51	3.70	.....	.....	R.	802½	Closed May 1
Point Manoir	Apr. 30	May 23	571	2.82	.....	.....	R.	802½	Do.
Lobdell	Apr. 22	May 23	1,081	7.22	4.12	58,892	R.	809	Closed May 7
Martines	Apr. 22	May 23	124	19.70	.....	.....	R.	816¾	
Nita	Mar. 14	May 23	2,892	15.00	9.28	402,556	L.	842½	Closed Apr. 2
Corinne	Feb. 13	.....	25	.....	.....	.....	L.	899	
Do	Mar. 26	.....	30	.....	.....	.....	L.	.....	Closed Feb.
Do	Mar. 26	.....	25	.....	.....	.....	L.	973½	Closed Mar. 3
Bertrandville	Feb. 23	.....	10–15	.....	.....	.....	L.	.....	Do.
Live Oak	Mar. 20	Mar. 26	116	6.50	7.75	5,881	L.	990½	Closed Feb. 2
Woodland	Mar. 22	.....	10	.....	.....	.....	R.	991¼	Closed Apr. 1
Myrtle Grove	Mar. 21	May 6	540	5.50	2.18	6,474	L.	992¼	Closed Mar. 2
Do	Mar. 21	May 6	295	3.50	5.04	5,153	R.	.....	.....
St. Sophie	Feb. 13	.....	75	.....	.....	.....	R.	999½	.....
Do	Mar. 4	.....	70	.....	.....	.....	L.	.....	Closed Feb.
Do	Mar. 7	.....	15	.....	.....	.....	L.	.....	Closed Mar.
Do	Apr. 21	Apr. 23	54	12.00	10.00	6,480	L.	.....	Closed Mar.
Do	Apr. 21	Apr. 23	22	9.00	10.00	1,980	L.	.....	Closed Apr. 3
Do	Apr. 21	Apr. 23	71	9.00	10.00	6,390	L.	.....	Do.
Do	Apr. 21	Apr. 23	50	6.00	10.00	3,000	L.	1,000½	Do.
Do	Apr. 21	Apr. 23	21	5.00	10.00	1,050	L.	.....	Do.
Do	Apr. 21	Apr. 23	40	5.50	10.00	2,200	L.	.....	Do.
Do	Apr. 21	Apr. 23	38	4.75	10.00	1,705	L.	.....	Do.
Harlem	Mar. 21	Mar. 23	50	8.00	11.00	4,312	L.	.....	Do.
Do	Mar. 26	.....	10	.....	.....	.....	L.	.....	Closed Mar. 5
Do	May 10	.....	15	.....	.....	.....	L.	1,003½	Closed Mar. 7
Thibauts	Apr. 21	.....	10	.....	.....	.....	L.	.....	Closed May 1
Do	Apr. 21	.....	12	.....	.....	.....	L.	1,008½	Closed Apr. 2
Empire Mills	Mar. 14	.....	15	.....	.....	.....	L.	1,008½	Do.
Do	Mar. 26	.....	15	.....	.....	.....	L.	.....	Closed Mar. 5
Bohemia	Mar. 19	.....	30–50	.....	.....	.....	L.	1,012½	Closed Mar. 2
Do	Mar. 28	.....	6	.....	.....	.....	L.	.....	Closed Mar. 4
Do	Mar. 28	.....	10	.....	.....	.....	L.	1,015½	Closed Mar. 2
Riceland	Apr. 19	.....	60	6.00	8.00	4,800	R.	1,017	Closed Apr. 1
New Texas Landing	Feb. 24	.....	30	.....	.....	.....	L.	1,020½	Closed Feb. 2

* In line of levee around Lake Concordia 3½ miles south of a point 692 miles below Cairo.
† In a line of levee on Raccourci River 6½ miles south of a point 770 miles below Cairo.

CLOSURE OF CREVASSES.

As soon as a crevasse occurs and its destructive effects become felt there is alw a great demand that it should be closed. It is generally impossible to close them a day or two after they break, if the levee is of any considerable height. But w the country back of the levee becomes partially filled with water, so that the velo in the crevasse is somewhat reduced, they can, if the conditions are favorable, closed with material, which can always be easily obtained, and at a cost which we seem to be justifiable. The circumstances would be considered favorable where t levee is situated at a considerable distance from the river, so as to leave a battur a hundred feet or more in width, and also where the water on the bottom is not m than 8 feet in depth. While it is not impossible to close a crevasse in a greater depth water, the risk and the expense become very much greater after the depth passes th limit which I have given. A great many crevasses were closed in my district dur

he present high water, and while the methods were somewhat varied, the following lesign, which is illustrated in the plan, section, and elevation transmitted herewith, ontains all of the best features of the various methods which were used, and is essenially the same as that employed at Raccourci and Preston. The materials used are ? by 4 inch scantling, inch boards 12 inches wide, and sacks. The method consists n constructing a trestle bridge with light bents, placed about 2 feet apart, starting rom each end of the levee on the river side and far enough from the crevasse opening so that there is no danger of the structures being turned during the process of losure. This bridge is carried outward from the batture until it gets far enough way from the levee to pass beyond the deep hole which is almost always excavated n the throat of the crevasses; the two ends of the bridge then turn towards each ther, and are built in this direction till they meet. For a depth of water of 6 feet six piles should be used in each bent; they are capped with boards, as shown in the section, which serve at the same time to brace them. The bents are fastened together longitudinally by four lines of boards on edge, and the bridge is floored as indicated upon plan so as to leave an opening about 3 feet wide in the center. All parts of the structure should be firmly nailed together so as to secure the greatest amount of stiffness. Outside of the inner row of piles a strip of 2 by 4 scantling is firmly nailed to the caps to hold the heads of the small piles which are afterwards put in to form the grating. While the bridge is being constructed a force is employed filling sacks with earth. The sacks must be all filled full and well and tightly sewed. As they are filled they are carried upon the bridge and piled up until a sufficient number of them have been placed to form a levee which will completely close the crevasse. After this is done a sufficient number of pickets made of 2 by 4 scantling are prepared and quickly driven, as indicated upon plan, so as to form the grating on the land side of the bridge close enough to keep the sacks from washing through. When this is ready a large force of men should be assembled upon the bridge, and at a given signal they throw the sacks through the opening. The work must be carried on as rapidly as possible, and must not cease until the pile of sacks rises above the surface of the water. Any leakage which then develops can be stopped by dumping earth from the bridge upon the river side of the levee. All the piles for the trestles as well as for the grating are driven with hand mauls, and no heavy pieces of timber or expensive appliances are required for the work. Where the water is not more than 3 or 4 feet deep the structure can be simplified by omitting the two piles on the river side of each bent. The sacks, however, ought to be thrown into the water through the opening as indicated on the large trestle, in order to give a safe width of base to the levee to enable it to make a good joint with the surface of the ground. This kind of work has been successfully used for a short distance where the water was as much as 14 or 15 feet deep.

THE FLOOD OF 1890.

The high water of 1890 will long be remembered in the Mississippi Valley as the highest and the largest flood that has ever occurred of which we have any authentic record. There are, to be sure, a few points on the river where the conditions have been modified by cut-offs where the present flood has been surpassed by some preceding ones, but these cases are exceptional and are easily accounted for, and do not affect the great portion of the river. The flood was doubtless due to the exceptionally heavy rainfall in the Ohio Valley, and also in the valleys of the subordinate tributaries of the river, for the great tributary, the Missouri and the Mississippi itself, were neither of them at a very high stage at any time during the flood. The flood heights at the various stations of observation, the form of the flood wave and the various phenomena connected with it can best be studied by a graphical representation, and I have therefore prepared a drawing which shows the plan of the river with the points at which gauges are established marked upon it. It also shows the location of the levees, the railways, the bluffs, and other topographical features. An examination of this map will show that the gauges are well placed to give a good idea of the flood along the whole river, and that they are near enough together to disclose all of the abnormal features of the wave.

The drawing also shows, by the heavy lines, the gauge heights at the various stations where observations were taken during the entire dangerous period of the flood; that is to say, from the 1st of March until about the 5th of May. I have also put upon this drawing, for the purpose of comparison, the corresponding hydrographs of the flood of 1882. At Red River Landing I have also given the gauge curve for Barbre's Landing plotted to the same absolute zero. This gauge, it will be noted, is at the head of the Atchafalaya River, and a study of it serves to show the influence that the Atchafalaya flood exerted upon that in the Mississippi; I have also marked the location of the different crevasses that occurred in my district, and I have indicated the dates at which they occurred, the dates at which their discharges were measured, and also the volume of discharge of each. I have also given the discharge curves for the Red River Landing section, and for the Carrollton section, and have

noted the discharges at Warrenton, Natchez, and Baton Rouge at the dates at wh they were taken.

A study of this sheet shows that there were two flood waves, the first of which c minated between the 15th and 20th of March, and the second between the 20th a the 25th of April. The first wave was a normal one for all points above Don sonville; that is to say, the flood water was entirely confined within the banks by levees. The second one was an abnormal one, and was influenced and modifie the crevasse water which had escaped through the crevasses above Vicksburg, a which returned to the river at the mouth of the Yazoo and at the mouth of R River.

The hydrographs of Vicksburg, St. Joseph, and Natchez are similar throughc they form a group which differs from those below them, and they show very plai when compared with the curves for Red River Landing and Bayou Sara, the influe of the Atchafalaya as an outlet.

At the beginning of March, as shown by the curves, the Atchafalaya was lov than the Mississippi, and it was acting therefore as an outlet, and its effect is evid from the fact that the Red River Landing gauge was relatively much lower th those above.

The first crevasse in Tensas Basin, above my district, occurred in the early par March, the Sappington was on the 8th of March, and this was followed by Raleigh on the 15th and the Luna on the 18th. As the crevasse water reached t head of the Atchafalaya, this gauge began to rise and soon came to the level of t Mississippi at Red River, and the two curves are coincident. After the 15th Barb gauge rises above that at Red River Landing and the Atchafalaya becomes a tributa instead of an outlet. The influence of this tributary is very peculiar and very mark in this case. By examining the discharge curves before alluded to, we find a max mum discharge at Red River Landing occurring about the 17th and 18th of Mar It is to be regretted that there were not a greater number of discharge observati taken at Red River Landing between the 5th and 18th of March, because the curve not very fully delineated. It is quite apparent, by comparing it with the curves Carrollton, that the discharge of March 18 could not have been the maximum d charge. However, we see that the discharge fell off very rapidly after the 18th March, and that it did not again attain as great a volume until about the 15th April, nevertheless, the Red River Landing gauge maintains the same height fr the 15th up to the end of March, which would seem to indicate that the retu water had been heaped up upon the surface of the Mississippi River at this point, a had increased its height without increasing its discharge. The fact that it did is proved, first, by the study of the gauges above Red River Landing we see th the Vicksburg, the St. Joseph, and the Natchez gauges all fell about 1.5 feet from th 15th to the 31st of March. This is exactly what should have taken place, d to the diminished discharge, and that from the 1st of April to the 15th of April the gauges gradually rose again and attained, on the 15th of April, a height about equ to what they had on the 15th of March, at the time of the March flood. But at R River Landing there was no fall after the 15th of March, but from the 1st of April the 15th of April the gauge height increased 2.4 feet, and this same fact is ob served to a lesser extent at Bayou Sara, 35 miles below Red River Landing; he there was a slight fall of about .3 foot up to the end of March, and from the e of March to the 15th of April there was a rise of about 2.2 feet, or a gain of 1.9 fe from the crest of the March flood. At Baton Rouge the fall to the end of March wa greater than at Bayou Sara, and subsequent rise was less. At Plaquemine, st lower down the river, the fall in March was still greater than at any of the point above to Red River Landing and the subsequent rise was also less, showing that th heaping up of the water at Red River Landing due to the return crevasse water, ma itself felt down as far as Baton Rouge, a distance of 70 miles, and that it did n make itself felt at Plaquemines, a distance of 90 miles.

The first crevasse to occur in my district was the Nita Crevasse, a break wh took place in the levee on the left bank of the river about 5 miles above Coll Point. The break, in spite of all efforts to control it, increased rapidly, and on t 22d of March it had a discharge of about 90,000 cubic feet a second. Its influen is very plain upon the College Point gauge, 5 miles below. Its effect was sufficie to prevent the College Point gauge from ever again attaining a height as great a that which it had in March. We observe on this hydrograph a gradual fall from t time that this crevasse occurred until the end of the flood. The discharge of the N Crevasse increased very rapidly; from 90,000 cubic feet a second on the 22d of Mar it increased to 400,000 cubic feet a second on the 7th of May. At that time it becam equal to one-third of the entire discharge of the river. Notwithstanding this enormous escape, however, through this outlet, the actual fall directly traceable to th crevasse, or the gauge at College Point from its highest point, was only about 1.9 feet and since this highest point was nearly 24 feet, if the fall had corresponded to the los of discharge it ought to have amounted to as much as 8 feet. At Carrollton the influence of this crevasse as an outlet can be traced to be sure, but its influence was ver

much less than at College Point, and the fall due to it may be stated to be about 1 foot. This, even, at a time when this escape must have been at least one-fourth of the entire discharge of the river.

As the second flood wave approached its culmination, the river below the mouth of Red River Landing attained a height greater than any of which we have any authentic record, and the levees were taxed to a point beyond which they were ever expected to resist. On the 21st of March a very severe storm set in; very heavy rainfall, accompanied by a gale from the east and southeast; the levees, saturated as they were by long exposure to a height of water which reached almost to their crowns, were unable to withstand the force of the storm and yielded at a great many places. Above the mouth of Red River there was a crevasse at Lake Concordia, another at Arnauldia, another in the Henderson-Ashley Levee.

Below the mouth of Red River crevasses occurred during the period of the storm at Raccourci, Upper Morganza, New Morganza, Smead, Lanaux, Fannie Richie, Preston Taylor, Lobdell, and Martinez, some nine or ten crevasses in a distance of about 60 miles. These crevasses discharged in the aggregate, within two to three days of the time when they occurred, a volume of nearly 300,000 cubic feet a second. The effect of this enormous loss of water from the river was to cause a rapid lowering of the surface upon that portion of it directly influenced by the crevasses, and we note at Bayou Sara, Baton Rouge, and Red River a loss of height of 1 foot or more in a period of two or three days. The greatest fall is at Baton Rouge, as it is below all the important breaks; the least fall is at Red River Landing, because it is above most of the breaks and because this loss of water was largely compensated by the increased amount of water which it drew from the Atchafalaya as soon as the Mississippi began to fall.

Above the mouth of Red River, at Natchez, the abrupt fall is very slight, amounting only to 3 or 4 inches. At St. Joseph and Vicksburg, the fall was normal and was simply due to the fall in the river above. It therefore may be seen that the influence of these enormous outlets thus suddenly let loose at the flood height was something, to be sure, but it was very insignificant in comparison with the amount of water drawn from the river. It is further to be noted that its effect is almost entirely felt below the points at which the crevasses occurred, and that at a comparatively few miles above the crevasses the effect ceases and amounts to nothing. There could not be a more forcible object lesson than this upon the worthlessness of outlets as a means of controlling floods.

We find, in addition to the crevasses which I have mentioned, others occurring at Live Oak, Harlem, Riceland, St. Sophie, and Myrtle Grove. All of these breaks occurred below the City of New Orleans; most of them were closed, to be sure, within a week or two after they happened, but Myrtle Grove has not yet been closed, but in examining the Carrollton gauge-curve we can not trace any effect due to any of these breaks below the city. A comparison of the discharge curves at Red River Landing and Carrollton would seem to indicate that there was a less loss of water through these crevasses that I have described as occurring between those two points than results from adding together the discharges that I have given. For example, about the end of April, when all the crevasses were open, there is a difference in the discharge between these two points, as shown by the curves, of less than 500,000 cubic feet a second, yet the escape through all the crevasses at this time must have been at least 700,000 cubic feet a second; but this difference is accounted for by the fact that the river was falling and the water passing the Carrollton section was necessarily greater per second than that passing Red River Landing section, due to the reservoir capacity of the main trunk of the river itself between these two points, for the river between these two points was lowered some 2 or 3 feet in a period of a few days, and its enormous volume of water would furnish a very considerable discharge in itself; in addition, the rainfall, which was very heavy below Red River, would be sufficient to add materially to the discharge.

IMPROVING MISSISSIPPI RIVER (NO LIMIT).

Money statement.

(*a*) Levees on Tensas Front:		
July 1, 1889, amount available		$87,190.84
March 19, 1890, amount transferred to protection of levees	$10,000.00	
July 1, 1890, amount expended during fiscal year, exclusive of liabilities outstanding July 1, 1889	48,073.42	
July 1, 1890, amount covered by uncompleted contracts made during the fiscal year ending June 30, 1890	21,419.63	
		79,493.05
July 1, 1890, balance available		7,697.79

noted the discharges at Warrenton, Natchez, and Baton Rouge at the dates at which they were taken.

A study of this sheet shows that there were two flood waves, the first of which terminated between the 15th and 20th of March, and the second between the 20th and the 25th of April. The first wave was a normal one for all points above Donaldsonville; that is to say, the flood water was entirely confined within the banks by the levees. The second one was an abnormal one, and was influenced and modified by the crevasse water which had escaped through the crevasses above Vicksburg, and which returned to the river at the mouth of the Yazoo and at the mouth of Red River.

The hydrographs of Vicksburg, St. Joseph, and Natchez are similar throughout; they form a group which differs from those below them, and they show very plainly when compared with the curves for Red River Landing and Bayou Sara, the influence of the Atchafalaya as an outlet.

At the beginning of March, as shown by the curves, the Atchafalaya was lower than the Mississippi, and it was acting therefore as an outlet, and its effect is evident from the fact that the Red River Landing gauge was relatively much lower than those above.

The first crevasse in Tensas Basin, above my district, occurred in the early part of March, the Sappington was on the 8th of March, and this was followed by the Raleigh on the 15th and the Luna on the 18th. As the crevasse water reached the head of the Atchafalaya, this gauge began to rise and soon came to the level of the Mississippi at Red River, and the two curves are coincident. After the 15th Barbre gauge rises above that at Red River Landing and the Atchafalaya becomes a tributary instead of an outlet. The influence of this tributary is very peculiar and very marked in this case. By examining the discharge curves before alluded to, we find a maximum discharge at Red River Landing occurring about the 17th and 18th of March. It is to be regretted that there were not a greater number of discharge observations taken at Red River Landing between the 5th and 18th of March, because the curve is not very fully delineated. It is quite apparent, by comparing it with the curves at Carrollton, that the discharge of March 18 could not have been the maximum discharge. However, we see that the discharge fell off very rapidly after the 15th of March, and that it did not again attain as great a volume until about the 15th of April, nevertheless, the Red River Landing gauge maintains the same height from the 15th up to the end of March, which would seem to indicate that the return water had been heaped up upon the surface of the Mississippi River at this point and had increased its height without increasing its discharge. The fact that it did so is proved, first, by the study of the gauges above Red River Landing we see that the Vicksburg, the St. Joseph, and the Natchez gauges all fell about 1.5 feet from the 15th to the 31st of March. This is exactly what should have taken place, due to the diminished discharge, and that from the 1st of April to the 15th of April the gauges gradually rose again and attained, on the 15th of April, a height about equal to what they had on the 15th of March, at the time of the March flood. But at Red River Landing there was no fall after the 15th of March, but from the 1st of April to the 15th of April the gauge height increased 2.4 feet, and this same fact is observed to a lesser extent at Bayou Sara, 35 miles below Red River Landing; here there was a slight fall of about .3 foot up to the end of March, and from the 1st of March to the 15th of April there was a rise of about 2.2 feet, or a gain of 1.9 feet from the crest of the March flood. At Baton Rouge the fall to the end of March was greater than at Bayou Sara, and the rise was less. At Plaquemines, still greater than at any of lower down the river, the fall in March was still greater than at any of above to Red River Landing and the subsequent rise was also less, showing heaping up of the water at Red River due to the return crevasse itself felt down as far as Baton Rouge, a distance of 70 miles, and make itself felt at Plaquemines, a distance of 90 miles.

The first crevasse to occur in my district was the Nita Crevasse, which took place in the levee on the left bank of the river about 5 miles below Point. The break, in spite of all control it, increased to a discharge of 22d of March it had a discharge of 300 cubic feet a second, which is very plain upon the curves. College Point gauge attaining to prevent the College Point gauge attaining a height that which it had reached. This hydrograph time that this crevasse occurred during the flood. Crevasse increased rapidly; on the 7th of March it increased to 400,000 cubic feet a second, or about equal to one-third of the river. mous escape, however, actual flood crevasse, or the gauge highest and since this highest of discharge it ought to be assumed once of this crevasse as

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to withstand the force of the storm and yielded at a great many places. Above the
mouth of Red River there was a crevasse at Lake Concordia, another at Arnauldia,
another in the Henderson-Ashley Levee.

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at Ruccourci, Upper Morganza, New Morganza, Smead, Lanaux, Fannie Riche, Pres-
ton Taylor, Lobdell, and Martinez, some nine or ten crevasses in a distance of about
60 miles. These crevasses discharged in the aggregate, within two to three days of
the time when they occurred, a volume of nearly 300,000 cubic feet a second. The
effect of this enormous loss of water from the river was to cause a rapid lowering of
the surface upon that portion of it directly influenced by the crevasses, and we note
at Bayou Sara, Baton Rouge, and Red River a loss of height of 1 foot or more in a pe-
riod of two or three days. The greatest fall is at Baton Rouge, as it is below all the
important breaks; the least fall is at Red River Landing, because it is above most of
the breaks and because this loss of water was largely compensated by the increased
amount of water which it drew from the Atchafalaya as soon as the Mississippi began
to fall.

Above the mouth of Red River, at Natchez, the abrupt fall is very slight, amount-
ing only to 3 or 4 inches. At St. Joseph and Vicksburg, the fall was normal and
was simply due to the fall in the river above. It therefore may be seen that the
influence of these enormous outlets thus suddenly let loose at the flood height was
something, to be sure, but it was very insignificant in comparison with the amount of
water drawn from the river. It is further to be noted that its effect is almost entirely
felt below the points at which the crevasses occurred, and that at a comparatively
few miles above the crevasses the effect ceases and amounts to nothing. There could
not be a more forcible object lesson than this upon the worthlessness of outlets as a
means of controlling floods.

We find, in addition to the crevasses which I have mentioned, others occurring at
Live Oak, Harlem, Riceland, St. Sophie, and Myrtle Grove. All of these breaks occurred
below the City of New Orleans; most of them were closed, to be sure, within a week
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breaks below the city. A comparison of the discharge curves at Red River Landing
and Carrollton would seem to indicate that there was a less loss of water through
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the end of April, when all the crevasses were open, there is a difference in the dis-
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at least 700,000 cubic feet a second; but this difference is accounted for by the fact
that the river was f[illegible] and the water passing the Carrollton section was neces-
arily greater per s[illegible] n that passing Red River Landing section, due to the
ervoir capacity [illegible] trunk of the river itself between these two points, for
river between [illegible] points was lowered some 2 or 3 feet in a period of a few
s, and its enorm[illegible] of water would furnish a very considerable discharge
itself; in additi[illegible] all, which was very heavy below Red River, would be
icient to add m[illegible] he discharge.

G MISSISSIPPI RIVER (NO LIMIT).

Money statement.

(a) Levees [illegible]

1889, amou[illegible] nt:

19, 1890, a[illegible]

1890, amou[illegible] red to protection of levees.. $10,000.00 $87,190.84

ties outsta[illegible] ring fiscal year, exclusive of

1890, amou[illegible] 9..... 48,073.42

the fisca[illegible] ompleted contracts made

30, 1890..... 21,419.63

79,493.05

90, bala[illegible] 7,697.79

(*b*) Protection of levees, fourth district:		
Amount allotted from act of August 11, 1888		$114,0
July 1, 1890, amount expended during fiscal year, exclusive of liabilities outstanding July 1, 1889	$95,839.87	
July 1, 1890, outstanding liabilities	147.49	
		$95,9
July 1, 1890, balance available		18,0
(*c*) Protection of levees on Tensas Front, fourth district:		
July 1, 1889, amount available		19,3
July 1, 1890, amount expended during fiscal year, exclusive of liabilities outstanding July 1, 1889		19,3

IMPROVEMENT OF THE HARBOR OF NEW ORLEANS, LOUISIANA.

The tendency of the Mississippi River at New Orleans, as elsewhere, is to cut undermine, wash away, and destroy its concave banks, whereby the crossings are dered more abrupt, and the bars at the points or convex banks extended. This ac is exceedingly injurious at places like New Orleans, where the city occupies both ba of the river, for in the bends, levees, streets, and warehouses are gradually un mined and destroyed, while the growth of bars elsewhere prevents access to wha and docks. To resist and overcome this tendency to change, and to hold the r permanently in its present lines, is the sole object sought to be attained in the provement of New Orleans Harbor.

The works employed to accomplish this end now consist of submerged spur-d with sloping crests, placed in the bends at proper intervals, the object being to vent erosion by checking the velocity of the current along the shore, to force the of deepest water farther from the shore, and, if possible, to induce deposit betw the spurs, thus reducing and equalizing the slope of the bank. The top of these s is generally placed at about the low-water line, and the crest slopes downwards a angle of about 1 on 3, so as to place the toe at the deepest portion of the river. axis of the spur is placed perpendicular to the direction of the current or else clined slightly up-stream. The spurs, which rest on a wide mattress, are built of ber, willow-brush, and stone.

The portions of the river where this kind of work was considered necessary w as follows:

The Carrollton Bend, length	1
The Greenville Bend, length	5
The Gouldsboro Bend, length	4
The third district, length	2
Total	52

In pursuance of this general project the following work had been done prior July 1, 1889: A continuous mattress about 400 feet in length had been placed at head of the Carrollton Bend. This kind of work has since been abandoned. spur-dikes had been constructed in the Gouldsboro Bend, which completed the w proposed at that point. One very large spur had been partly built in the Green Bend near the company's canal. A survey of the harbor had been made, and pl and estimates prepared for the continuation of the work. The plant had been pu good order, and a large quantity of lumber, brush, and rock had been procured was conveniently stored for spur-dike construction.

During the past year the dike in the Greenville Bend was completed, and a sec spur about 1,000 feet below it built. This was all the work that the approved p ect called for in that locality for the present. In addition to this four spur-di were built in the third district of the city of New Orleans, completing the impro ment at that point.

Spur No. 1, in the Greenville Bend, is worthy of special mention as being the larg structure of its kind ever placed in the Mississippi River or elsewhere, so far know. It contained in round numbers 3,400 cords of willow brush, 80,000 fee lumber, 2,000 tons of rock, 5,500 pounds of wire, 60 kegs of nails and spikes, and pounds of iron rods and chains. Its length was 430 feet; its maximum height 60 and the depth of the water at its outer end was 152 feet at low water.

Dike No. 2 was a little longer than the one just described, but it was only abou feet high and contained very much less material. These two spurs have been posed to the recent high water. What their condition now is can not be determin till the river reaches a stage low enough to permit soundings to be taken over the The bank has not caved at any point within the area which they are designed to p

ect. The velocity of the current next the bank has evidently been reduced, and the ine of greatest velocity has been pushed out from the bank. I think that they are ccomplishing all that is required of them, and that there is every reason to antici- ate that the spurs will be found in good condition, and that the mean slope of the ank in the area influenced by them will be somewhat reduced.

The spurs in the third district differed from those heretofore constructed in the arbors, in this, that they were carried above the low-water line. The river at this oint had encroached so far upon the city that it had been necessary to move the evee back until it occupied one-half of a street running parallel to the river, and ractically destroyed the street. It was therefore important to stop absolutely the ecession of the bank line, and if possible to reclaim a little land from the river. The purs were therefore carried up over the batture and connected with the levee, and at he point of junction they were given the same height as the levee itself. The sub- queous portion of the spurs was constructed in the same manner as those heretofore escribed, and the spur was prolonged from the low-water line to the main levee y a bank of earth of the proper dimensions, which was protected from wave-wash nd scour due to overfill by a layer of gravel or broken stone 9 inches thick, upon hich a rough stone pavement of like thickness was laid. This covering extended ut upon the batture for a distance of 20 feet from the toe of the up-stream slope and 0 feet from that of the down-stream one. It was also carried out to connect with he foundation mattress. The work was done last autumn under favorable circum- tances, with a low river, good weather, and a well-trained force of workmen under he immediate direction of a zealous and competent engineer, who thoroughly under- tood what he had to do. The work was therefore very good of its kind, and its cost ell considerably below the estimates. As in the case of the Greenville spurs, the xact condition of the work can not yet be fully determined. This much is evident, owever. The paved spurs have resisted the action of the waves and current per- ectly. There has been no loss of bank, and there has been a heavy deposit of silt of rom 1 to 3 feet in thickness upon so much of the batture as has thus far been un- overed by the falling river. I feel confident that this work will be a complete suc- ess, and I believe that this type may be advantageously adopted for the protection f the caving banks at many points higher up the river. One great advantage that t offers is its cheapness, and another is that the loss of one or more spurs does not ecessarily involve the loss of the whole system, even if it takes place at a time hen no funds are available for repairs.

The actual cost of the field-work in the third district, which is the only proper tandard of comparison, was $33,574.48, and it protects about 3,000 feet of caving ank, where the average depth of water is 90 or 100 feet. If this protection proves ntirely satisfactory, as I believe it will, it then presents a method of bank protec- ion costing only about $11 a running foot, a cost which is certainly very moderate.

I send herewith a drawing showing the location of the spurs in the third district, lso showing a section of each spur and the details of construction of the bank pro- ection.

There yet remains under the present project six spurs to be built in the Carrollton end. The following material is now on hand for this work:

,840 tons rock, at $2	$9,688.00
0,000 feet lumber, at $10.90	327.00
8 kegs nails, at $3	84.00
,420 pounds galvanized wire, at 4 cents	56.80
15 cords brush, at $1.68	193.20
0,000 pounds iron rods, etc., at 3½ cents	1,050.00
Total value	11,399.00

The work will be begun as soon as the river reaches a stage low enough to render t possible. The proposed location and mode of construction of the spurs is shown pon the accompanying drawing.

As this project was based upon a survey that was made a year and a half ago, and s the destructive forces of the river have not been idle during this period, it will loubtless be necessary to make some changes in the dimensions if not in the location f these spurs.

The only very valuable property which is immediately endangered by the caving of he bank in this locality is the large and fine wharf, warehouse, and elevator belong- ng to the Louisville, New Orleans and Texas Railroad. I regard this property as in a ery critical condition, and I am by no means sure that work done this season will be n time to save it. I am informed that there has been a great deal of scour in front f the wharf during the present high water, and that a great many piles have washed ose, and that it has been necessary to replace them with 90-foot sticks. This would eem to indicate that the bank is assuming a dangerously steep slope, and an exten- ive caving of the bank may be looked for at any time as the river falls. It will be

remembered that I recommended that this work should be done last year, in pre-
ence to that in the third district.

The plant and material belonging to the work in New Orleans Harbor is all in g
order and ready for use, excepting the tug, which on the night of May 8 took
and burned to the deck. The boat had a few hours before returned from the
Crevasse, whither it had been sent to be used in measuring the discharge.
cause of the fire is unknown, but after a careful investigation I am satisfied tha
was unavoidable and that no one was to blame. The loss will amount to a
$2,000. The boat is now being repaired and will be ready for use by the time
needed.

The commercial statistics of the port of New Orleans are now being comp-
They can not be completed, however, before the close of the fiscal year. The s
remarks will apply to my financial statement.

IMPROVING MISSISSIPPI RIVER (NO LIMIT).

Money statement.

New Orleans Harbor:		
July 1, 1889, amount available		*$126,73
Amount disallowed by Chief of Engineers (over-payment)		
		126,73
July 1, 1890, amount expended during fiscal year, exclusive of liabilities outstanding July 1, 1889	$78,215.07	
July 1, 1890, outstanding liabilities	4.26	
		78,21
July 1, 1890, balance available		48,51
Amount (estimated) required for completion of existing project		500,00
Amount that can be profitably expended in fiscal year ending June 30, 1892		200,00
Submitted in compliance with requirements of sections 2 of river and harbor acts of 1866 and 1867.		

THE RECTIFICATION OF THE RED AND ATCHAFALAYA RIVERS.

The objects to be attained by the rectification of the Red and Atchafalaya riv
are threefold, namely:

First. To prevent the further deterioration of the channel of the Mississippi Ri
at and near Red River Landing, due to the action of the Atchafalaya as an outlet.

Second. To afford at all stages of the two rivers a safe and easy entrance from
Mississippi to the Red River and its tributaries for all classes of vessels and tows t
navigate them.

Third. To secure like advantages for the Atchafalaya and its connecting wa
And it is also required as a condition that these results should be attained with
disturbing the high-water regimen of the rivers and streams involved, whereby p
erty would become subject to overflow which is now safe.

The approved project requires the construction of the following works: A seri
low dams, not exceeding six in number, is to be built across the Atchafalaya Rive
low the mouth of Bayou des Glaizes to prevent the further enlargement of the Atc
alaya and to limit its outlet capacity. These dams have a maximum depth o
their crests of 7 feet at extreme low water, and at high water permit a discha
over them equal to the entire flow of Red River, say 200,000 cubic feet per sec
In addition to this, a low dam is to be built across Old River from the west s
of Turnbull's Island to the mainland, and between the old mouth of Red River a
the head of the Atchafalaya. The crest of this dam is to have a suitable eleva
above the obstructions in the Upper Old River, its object being to force the Red R
when below a certain stage to flow through Upper Old River, which, before the p
ent conditions induced by the enlargement of the Atchafalaya, was its natural
better channel. To still further control the flow of Red River at low and interme
stages, it is proposed to build a jetty from the lower end of Turnbull's Island along
middle of Old River and extending outward into the Mississippi. This jetty is to
a height in due relation to that of the Red River Dam, and a form in plan such a
deliver the Red River water to the Mississippi with the minimum amount of sh
Its effect will be to force the current, during the falling and low stages of the riv

* This is the correct amount available July 1, 1889, not $126,634.65, as printed
Appendix V V, page 2721, of the Annual Report of the Chief of Engineers for 18

to flow from the Red to the Mississippi River, and the current of the latter river sweeping past the end of the jetty will prevent the formation of the bar that is usually found at the mouth of a tributary. These works will also secure an easy entrance to the Atchafalaya; for this river, being deprived of all water from the Red River (when the level of the dam is reached), will become a proper outlet of the Mississippi, and will be permitted to take an amount of water (to be regulated by the contraction works in the Atchafalaya) sufficient to maintain a channel through Lower Old River large enough and deep enough for all purposes of navigation. The Atchafalaya, though by these means reduced to an outlet of the Mississippi for a few months during the low-water season, will at other times carry the flood discharge of Red River, which will be ample to maintain its channel; and there is no reason to fear that it will deteriorate, as do the ordinary outlets of the Mississippi River. The same forces that are now acting to enlarge it will still act, under proper direction and control, to maintain its channel.

These works, being all of low relief, and situated in wide and deep portions of the rivers, will not interfere with their high-water regimen, and no place in the valley which is now safe will be rendered liable to overflow.

In addition to this, the annual projects for many years have contained provisions for maintaining navigation through Old River during the low-water season by various temporary devices, such as dredging, washing with the wheels of steam-boats and tugs, dragging along the bottom scrapers attached to steam-boats, contracting the channel by temporary wing-dams, blowing up the mud lumps with dynamite, etc. These expedients have succeeded when the conditions were favorable, and have generally failed wholly or in part when they were not. But they always afforded some relief, and while they certainly cost a great deal of money in the aggregate, the work was doubtless worth what it cost. The worst that can be said of work of this character is that it is of no value after the season in which it is done. It is therefore greatly to be desired that the appropriations for this work should be large enough to permit the permanent works soon to be finished, in order that this annual drain may cease.

It may perhaps be well to state here that it has often been asserted that, but for the work done from year to year by the United States for the purpose of maintaining a navigable channel through Old River during the low-water season, this channel would have become so filled up as to be practically closed, and the Red and Atchafalaya rivers thus divorced from the Mississippi; a condition which is regarded by certain persons not interested in the navigation of the river as very desirable. But this is not the case. Nothing of the kind would have taken place. It may be definitely stated that the influence upon the permanent condition of Old River produced by any work that has been done there in the last ten years is infinitesimal, if it is not absolutely zero. A greater change is wrought upon the bottom of Old River in three or four days by a sudden flood in Red River when the Mississippi is low than could be produced by washing and dredging all summer, and such floods occur almost every year.

In pursuance of the general plan thus briefly sketched out the following permanent work had been accomplished up to the 1st of July, 1889:

As stated in my annual report for the year ending July 1, 1888, a survey of the reach of the Atchafalaya below Bayou des Glaizes had been made to determine the proper location for the dams, a plant for the work had been procured, necessary temporary buildings had been erected on the bank, a deep well had been driven to secure a supply of potable water, and the sill for Dam No. 1 had been constructed. During the succeeding year a dredge, four dump-scows, and two large and well-equipped quarter-boats were added to the plant, the dam on Sill No. 1 was built, and the sill for Dam No. 3 was nearly completed, and some 26,000 tons of rock were quarried out and distributed for use at the different works in my district. Lumber and other material had also been procured and was on hand for the work. The balance available for the continuation of this work on July 1, 1889, was $88,560.23. Of this sum it was proposed to set aside $20,000 for the maintenance of a navigable channel through Lower Old River during the low-water season 1888 and 1890 by dredging or other temporary devices; also to set aside $5,000 for the protection of existing works till September 1, 1890, and also a sum sufficient to care for the plant and material when not in use until September 1, 1890. With what then remained it was proposed to complete Sill and Dam No. 3, in the Atchafalaya River, and to proceed with the construction of the dam near the head of Turnbull's Island as far as the funds then available would allow.

In accordance with this plan Sill and Dam No. 3 were completed August 27. The mode of construction was the same as in Dam No. 1. That is to say, the sill was first placed across the river between the low-water lines. It was formed of a single layer of mattresses. These mats were each 75 feet wide, 304 feet long, and 3 feet thick. They were built of willow brush and poles in layers at right angles, and were held together by timber clamps. These mats were sunk in succession, side by side across the river, thus forming a sill 304 feet wide. That portion of the sill between the

low-water line and the crest of the bank was similar to the subaqueous por but it was constructed in place and was therefore continuous. The whole v anchored and held securely in place by rock. About 42 pounds to the squar of surface of mat was used; four times as much as was necessary to sink a ma the bottom. The dam was built up of layers of mattresses like those in the These mats were so proportioned as to give to the dam when completed slopes of one on three and a width of crown of 30 feet. On the top of each la mats when sunk a quantity of stiff blue clay was spread, in order that it might fil spaces between the willows and make the dam tight. An extra quantity of was placed on the top mat for greater security. These two dams have withstood unprecedented flood of this year, and as far as can be ascertained at the present h stage of the river they are uninjured. But owing to the fact that the clear wa way at the extreme flood stage over the top of Dam No. 3 was less than over No the fall was concentrated at this place, and the velocity of the current became so g as to be a serious obstacle to navigation. The mean area of cross-section of the r near Simmesport is about 60,000 square feet. The area over the top of Dam No. reduced to about 50,000 square feet; that over No. 3 is but 41,000. This is the verse of what it should be. The areas over the dams should increase from the up to the lower ones, in order that the fall may be uniformly distributed over them This is the case now for low stages of the river; for example, the area over No. zero of the gauge is 4,471 square feet, while over No. 3 it is 5,430. But this con effected for the flood-stage only by a further contraction at No. 1, or else by mo back the levees and otherwise enlarging the natural section at No. 3. The fo method will be the proper one, but it would have been imprudent to have made entire contraction at the time the dam was built, for it was the first one, and the tire concentration of all at a single point would have produced a velocity that w certainly have interfered with navigation and might have endangered the dam it

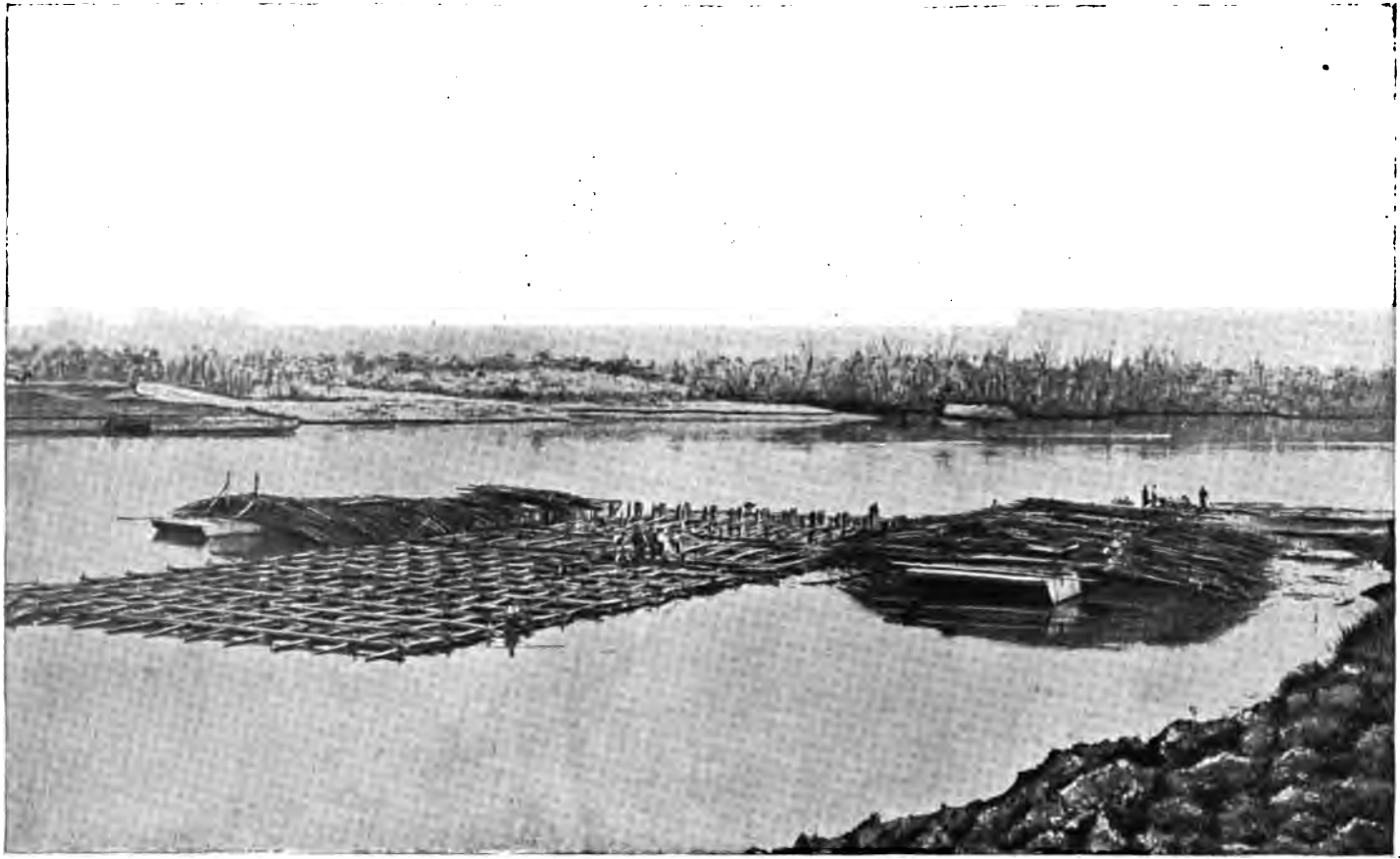
The flood area over No. 3 is still too large, if the discharge is to be limited to high-water discharge of Red River, say 200,000 cubic feet a second. When the tire system is completed the areas of flood discharge can be properly adjusted groins constructed on the sills between high and low water. During the pres high water the discharge down the Atchafalaya between levees was 414,281 c feet per second at 45.15 on the Simmsport gauge, and afterwards when the crevas below Simmsport became larger, thus allowing more water to leave the channel, discharge increased to 480,708, with a gauge height of 44.45. This caused a m velocity of 7.476 feet per second in a section of 64.301 square feet. Over Dam N the mean velocity must have been about 11.7 feet per second.

The Atchafalaya problem is influenced greatly by the question of overflow into it Tensas Basin. If the levees in Arkansas and North Louisiana are so built and ma tained as to prevent overflow in this basin, then the Atchafalaya will never be ov taxed. On March 6, 1890, the Atchafalaya was discharging past Simmsport 22 cubic feet a second, with a gauge height at Barbre's Landing of 42.3 feet. At h River Landing in the Mississippi the gauge was reading 43.0 feet. This was with the levees intact. On the 23d of April, when the effect of the return crevasse water fr the Tensas was at its height, and before the river was lowered by the large numb of crevasses that occurred about this time, Barbre's gauge read 49.7 and Red Riv Landing 48.77 (the highest ever known). Therefore, since the zero of the form gauge is 0.3 above that of the latter, the water-surface at Barbre's was due to crevasse water, at least $1\frac{3}{10}$ feet higher this year than it could possibly have been the Tensas levees had been perfect. This $1\frac{3}{10}$ feet was the "last straw"; without the Atchafalaya and Bayou des Glaizes levees could have been held, imperfect as they were, and the works at Simmsport would have fulfilled their purpose of limiting the discharge of the Atchafalaya, which, flanked as they were on both sides crevasses, they can hardly be said to have done.

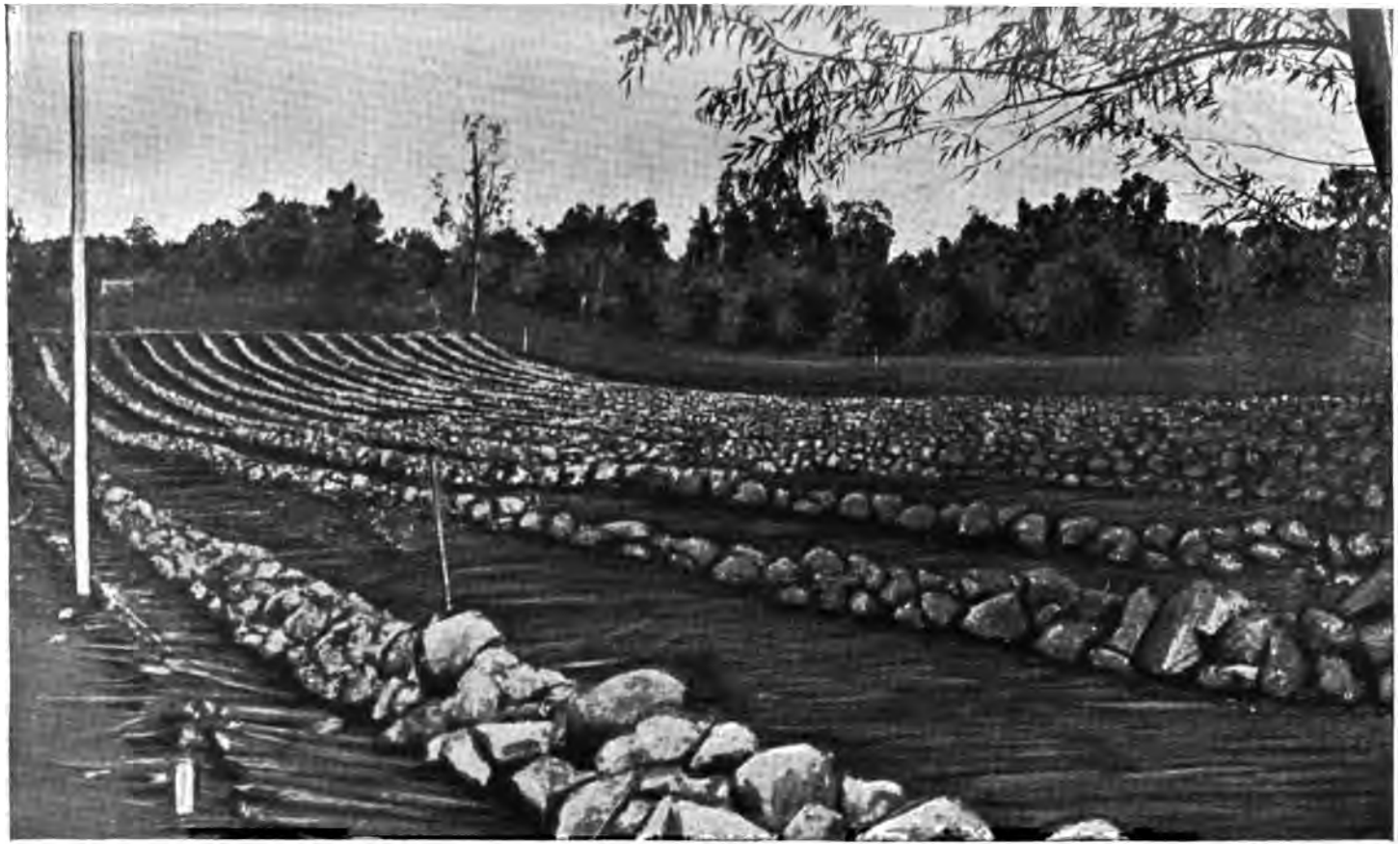
THE RED RIVER DAM.

In pursuance of the approved project the sill for this dam has been built. It crosses Old River at a point about three-quarters of a mile below the Sugar-house Chu upon the line approved by the Commission. The foundation as disclosed by a numb of borings is a fairly good one, being composed of river sand interspersed with la ers of red and blue clay. The sill was similar in construction to those in the Atch falaya. It is a good piece of work and was well and cheaply done. The details its construction are fully set forth in the report of Assistant Engineer Price, wh is transmitted herewith. A slight departure from the project was made in the man ner of placing the rock on the shore protection and on the sill where it crosses the bed of the slough. Instead of being uniformly distributed over the willow found tion, it was piled in parallel rows running lengthwise of the sill. These rows wer about 12 feet apart from center to center, and were about 2 feet high. The idea was that these rows or walls would cause a considerable deposit of silt between them

SILL NO. 3, ATCHAFALAYA RIVER, SHOWING BANK PROTECTION.



SILL NO. 3, ATCHAFALAYA RIVER: THE CONSTRUCTION OF A MATTRESS. SILL NO. 1 IN BACKGROUND.



RED RIVER DAM, SHOWING THE ARRANGEMENT OF THE ROCK WHERE THE SILL CROSSES THE BED OF THE SLOUGH.

us completely burying the willows, and that the ridges of rock would then be better le to resist the action of the current than a comparatively thin continuous layer. ie river has not yet fallen enough to show how far this expectation has been real- ed. Of course such a structure is not relied upon to resist the overfall at the dam. ie apron there is a strong mattress 3 feet thick, and is eventually to be covered with layer of rock in pieces of from 1 to 2 tons weight.

MAINTAINING A NAVIGABLE CHANNEL THROUGH LOWER OLD RIVER.

The low-water season was of short duration. The Red River Landing gauge regis- red less than 12 feet from the 2d of September until the 18th of November, and less an 6 feet from the 17th of October till the 13th of November. The lowest reading this gauge was 2.40 on November 5, on which day the Barbre's gauge recorded 50, the least reading there also. The conditions on the whole were not very unfa- orable. The principal reliance was placed upon the dredge for maintaining a chan- el. It was caused to work mainly upon the mud-lumps and ridges that are found at ntervals in the bed of Old River and which acted as dams. As these were cut away ie current was able to move the sand into the deep holes, and in this way a much reater quantity of material was gotten rid of than was actually moved by the dredge. he dredge itself gave good satisfaction, and although much interfered with by pass- ng boats it did its work at a moderate cost. I had much difficulty in the first place in etting a crew that understood it and could operate it.

Navigation was not entirely suspended in Old River at any time during the year, ut for a few days in the latter part of October and the beginning of November, be- ore the dredge had moved the mud-lumps at Ash Cabin, it was practical for small nd light-draught boats only. Navigation was completely restored at a lower stage han for many years, thus indicating that the dredge is the most efficient as well as he cheapest means of fighting low water at this place.

IMPROVING MISSISSIPPI RIVER (NO LIMIT).

Money statement.

Rectification of Red and Atchafalaya rivers:		
uly 1, 1889, amount available		$86,065.97
mount disallowed by Chief of Engineers (overpayment)		.10
		86,066.07
uly 1, 1890, amount expended during fiscal year, exclusive of liabilities outstanding July 1, 1889	$62,334.44	
uly 1, 1890, outstanding liabilities	5.02	
		62,339.46
uly 1, 1890, balance available		23,726.61
Amount (estimated) required for completion of existing project		650,000.00
Amount that can be profitably expended in fiscal year ending June 30,1892		350,000.00

Submitted in compliance with requirements of sections 2 of river and harbor acts of 1866 and 1867.

SURVEYS, EXAMINATIONS, AND INSPECTIONS.

Since my last annual report was submitted surveys have been made in the caving ends of the river near Lake St. Joseph, Lake Bruin, and Lake St. John. The ends f all these lakes are crossed by very large dikes, and if the river should cave in far nough to destroy these dikes it would be impossible to replace them by parallel lines n the rear, and it would be necessary to abandon many miles of the present levee nd construct an entirely new line passing to the westward of all these lakes and hrowing out a large number of fine plantations as well as greatly increasing the high- vater width of the river.

At Lake St. Joseph it was found that the caving extended down-stream from the ead of the lake for a distance of about 7,000 feet and up-stream for a distance of bout 10,000 feet, a total length of caving bank of about 17,000 feet. In comparing his survey with the survey of 1882 it is found that the maximum recession of bank below the lake is about 700 feet, the minimum about 550 feet, and the average about 600 feet. Above the lake these numbers are 800, 475, and 600, respectively, making an average annual loss of bank near the lake about 100 feet; 10,000 feet above the lake and extending up-stream for a distance of 7,000 feet farther, the caving has been very irregular and very much greater in quantity. In places it amounted to as much as 2,100 feet. If this rapid caving works down the bend it may involve the levee,

but if it does not the levee may be considered safe for some time to come, [illegible] 2,000 feet from the river-bank at present.

At Lake Bruin it appears that the caving bank is about 17,000 feet, and [illegible] pared with the survey of 1882, shows a recession opposite the lake of 1,800 fee[t] diminishes to 200 feet 5,000 feet below. The maximum recession is 2,900 fe[et] found at a point about 4,000 feet above the lake end. Caving diminishes to [illegible] 12,000 feet above the lake. This would give a maximum recession of bank over 400 feet per year, and as the levee is only 1,250 feet from the river, it seem likely that this levee can only last three years longer.

At Lake St. John the caving extends from Hole-in-the-Wall to a point 25,000 feet below. A comparison with the Mississippi River Commission sur[vey] 1885 shows a maximum recession of the bank line of 700 feet, at a point 6[,] above the lake end. From Hole-in-the-Wall Landing to Lake St. John, for a [dis]of about 17,000 feet, the maximum caving is 700 feet, minimum 200 feet, a[n] average 500 feet. In front of Lake St. John the caving amounts to only 200 f[eet] it does not exceed this amount at any point for 8,000 feet below. The present bank is 800 feet from the levee across the head of the lake. The nearest p[oint] the river-bank to any portion of this levee line where a break would do serious is 450 feet, and this is about one-half a mile above Lake St. John.

During the month of October, 1889, a survey was made of the Morganza Re[ach] the purpose of comparison with previous surveys. It may be stated that the [survey] that was made in 1886, at the time the crevasse was closed, showed that the[re] been a loss of effective area of cross-section of the river in the vicinity of the cr[evasse] of over 25 per cent since 1883. A survey made a year after the crevasse was [closed] in the fall of 1887, showed an increase of area of cross-section at the same p[oint] as much as 12½ per cent. The survey just referred to showed little or no cha[nge] the river channel since 1887. This may be readily accounted for by the fact that had been no very high water between these two dates; in fact the water had not high enough at any time to cause the levee to produce any marked effect on the men of the river. In addition to those surveys others have been made to det[ermine] the discharge of the crevasses, but these have elsewhere been reported.

GAUGES.

The gauge service in the fourth district of the Mississippi River has been well [main]tained throughout the year, and the results, as reported from time to time, [are] regarded as reliable. By request of the secretary of the Mississippi River [Com]mission I caused a large number of circulars to be distributed to reliable per[sons] my district, requesting them to mark in suitable manner the highest point r[each] by the flood. These circulars were distributed to persons living about 5 miles [apart] as near as was practicable, along the river, and these persons were requested to [report] the results of their observations to the secretary. I have therefore no mea[ns] knowing how well they performed their duty. From Mr. Perrilliat, of the Louis[iana] State board of engineers, I learn that the flood at New Texas Landing was 1 [foot] above that of 1882. Opposite Bayou Sara it was 1.59 feet; at Waterloo, 1.22 feet; at Hermitage, 1.78 feet. I believe these results to be reliable.

DISCHARGE OBSERVATIONS.

I had not intended in my district to do more during the present year than to se[cure] discharge observations at the time of maximum flood height, but when the [flood] promised to be an exceptionally large one I endeavored to procure as complete a [set] of observations as was possible. A good set of observations was obtained at Car[roll]ton, covering the entire period of extreme high water. A fairly good set was obtai[ned] at the mouth of Red River, but, as stated elsewhere, the number of observations [was] not sufficient in the early part of March to fully delineate the discharge curve. [Simi]lated observations were obtained at Warrenton, Natchez, and Baton Rouge. [The] results of all these measurements are transmitted herewith. Observations were [also] taken at Simmsport, on the Atchafalaya River. In speaking of these results as [not] good I do not mean to imply that the observations themselves were not trustwor[thy]. They were all carefully taken by competent men and with the very best appli[ances]. The fault with them was that they were not frequent enough. But this was unav[oid]able and due to the fact that I was obliged to detach most of my men during the [ex]treme high water and make use of their services in the more important work of [pro]tecting levees. The discharge observations therefore were necessarily taken at [such] times, when the services of the observers could be spared for this purpose.

The greatest discharge observed at Red River Landing was 1,487,362 cubic feet [per] second; this on the 7th of May. On the same day the discharge in the Atchafal[aya] River between the levees was 474,225 cubic feet per second. The escape at this [time] through two crevasses at Barbre's and Ferguson amounted to about 20,000 cubic

per second, and the escape through the crevasses in the levee of Bayou Des Glaize, which water was not measured in the Atchafalaya section, amounted to about 50,000 cubic feet per second at the same time. This would make the maximum discharge down the valley on a line drawn through Red River Landing to be about 2,021,617 cubic feet per second. This I believe to have been the greatest discharge as nearly as it is possible to determine it.

Discharge observations.

WARRENTON, MISSISSIPPI.

Date.	Area.	Mean velocity per second.	Discharge per second.	Area of overflow.	Velocity of overflow.	Discharge of overflow.	Vicksburg gauge.
1890.	*Sq. feet.*	*Feet.*	*Cubic feet.*				
Mar. 4	196,370	6.373	1,251,490	1,250	1.835	2,294	46.3
5	196,402	6.368	1,251,659	1,330	1.77	2,354	46.4
6	196,651	6.399	1,257,495	1,330	1.82	2,421	46.4
7	197,444	6.403	1,264,288	1,420	1.85	2,627	46.5
Apr. 11	206,567	6.417	1,325,568	1,760	1.86	3,278	47.5
12	207,267	6.536	1,354,725	1,920	1.86	3,611	47.7

NATCHEZ, MISSISSIPPI.

Date.	Area.	Mean velocity.	Discharge.	Gauge.
1890.				
Mar. 17, a. m	147,104	9.3953	1,382,089	46.65
17, p. m	147,104	9.4932	1,396,492	46.60

RED RIVER LANDING, LOUISIANA.

1890.				
Feb. 21	198,188	5.3468	1,032,939	41.78
22	196,942	5.3556	1,054,757	41.79
23	196,068	5.2951	1,038,199	41.84
24	195,874	5.3019	1,035,856	41.90
26	198,613	5.2542	1,043,557	42.27
27	197,264	5.265	1,038,606	42.39
28	197,938	5.338	1,056,593	42.58
Mar. 3	201,491	5.2762	1,063,111	42.77
18	209,042	6.0084	1,256,018	45.00
28	213,858	5.344	1,142,876	44.85
Apr. 1	215,574	5.3708	1,157,810	45.00
8	218,087	5.5322	1,206,519	46.05
12	219,019	5.6727	1,242,440	46.87
16	226,701	5.6674	1,284,801	47.56
18	230,752	5.6675	1,307,790	48.00
May 1	241,353	6.251	1,456,078	47.51
7	240,864	6.1751	1,487,362	47.29
10	242,000	5.754	1,392,403	47.00
13	235,849	5.832	1,375,630	46.75
15	240,794	5.719	1,377,169	46.61
20	229,018	5.812	1,331,105	46.10

SIMMESPORT, LOUISIANA.

1890.				
Mar. 6	50,492	4.365	220,399	40.80
19	54,393	5.0537	274,886	42.92
27	53,695	5.0057	268,788	42.95
Apr. 7	57,414	5.4285	311,675	44.25
10	58,302	5.8658	341,987	44.80
11	61,874	6.328	391,536	44.90
15	60,420	6.7855	409,982	44.90
17	60,162	6.886	414,281	45.15
May 6	63,288	7.4967	474,057	44.85
8	63,515	7.47	474,454	44.7
12	64,301	7.476	480,708	44.45
14	63,671	7.256	461,968	44.31
17	62,228	7.177	446,638	44.13
19	63,018	7.118	448,554	44.00

Discharge observations.—Continued.

BATON ROUGE, LOUISIANA.

Date.	Area.	Mean velocity.	Discharge.
1890.			
Apr. 26	199, 284	6.679	1, 331, 02[illegible]

DONALDSONVILLE, LOUISIANA.

In Bayou La Fourche.

Date.	Area.	Mean velocity.	Discharge.
1890.			
Feb. 21	5, 096	6.29	31, 96[illegible]

CARROLLTON, LOUISIANA.

Date.	Area.	Mean velocity.	Discharge.
1890.			
Mar. 3	179, 383	6.489	1, 164, 19[illegible]
4	179, 574	6.238	1, 120, 17[illegible]
5	181, 222	6.387	1, 157, 51[illegible]
6	175, 746	6.562	1, 153, 46[illegible]
7	175, 754	6.438	1, 131, 56[illegible]
8	174, 170	6.714	1, 169, 49[illegible]
10	186, 755	6.840	1, 277, 42[illegible]
11	185, 708	6.190	1, 149, 6[illegible]
13	185, 009	6.261	1, 158, 40[illegible]
14	187, 197	6.839	1, 280, 27[illegible]
18	186, 839	6.434	1, 202, 27[illegible]
19	186, 064	6.653	1, 237, 84[illegible]
20	190, 905	6.786	1, 286, 0[illegible]
21	192, 170	6.257	1, 202, 32[illegible]
22	188, 839	6.517	1, 130, 6[illegible]
24	192, 549	5.997	1, 154, 8[illegible]
25	191, 291	6.123	1, 171, 34[illegible]
26	189, 060	6.230	1, 177, 6[illegible]
28	184, 617	6.024	1, 112, 06[illegible]
29	181, 408	5.967	1, 082, 50[illegible]
31	182, 565	5.958	1, 087, 73[illegible]
Apr. 1	181, 119	5.663	1, 025, 63[illegible]
2	179, 908	6.296	1, 132, 64[illegible]
3	180, 639	6.116	1, 104, 74[illegible]
4	179, 266	6.029	1, 080, 85[illegible]
5	182, 045	6.033	1, 108, 22[illegible]
7	182, 444	6.039	1, 101, 89[illegible]
8	182, 068	6.027	1, 097, 4[illegible]
9	179, 134	5.997	1, 074, 37[illegible]
10	179, 598	5.929	1, 064, 86[illegible]
11	178, 851	5.715	1, 032, 24[illegible]
12	180, 015	5.788	1, 042, 00[illegible]
14	179, 789	5.718	1, 028, 2[illegible]
15	180, 033	5.732	1, 032, 00[illegible]
16	181, 543	5.601	1, 016, 74[illegible]
28	182, 165	5.536	1, 008, 46[illegible]
29	181, 180	5.478	991, 551
30	180, 572	5.437	981, 75[illegible]
May 1	179, 328	5.527	991, 15[illegible]
6	177, 634	5.264	937, 13[illegible]
14	179, 586	5.213	936, 17[illegible]

IMPROVING MISSISSIPPI RIVER (NO LIMIT).

Money statement.

Surveys, examinations, and inspections:		
ly 1, 1889, amount available		$594.44
ıount allotted from act of August 11, 1888, March 20, 1890		3,000.00
		3.594.44
ly 1, 1890, amount expended during fiscal year exclusive of iabilities outstanding July 1, 1889	$2,087.03	
ly 1, 1890, outstanding liabilities	.51	
		2,087.54
ly 1, 1890, balance available		1,506.90
Gauges, fourth district:		
ly 1, 1889, amount available		1,125.22
ly 1, 1890, amount expended during fiscal year exclusive of outstanding iabilities July 1, 1889		725.20
ly 1, 1890, balance available		400.02
Discharge observations:		
ly 1, 1889, amount available		2,460.41
ly 1, 1890, amount expended during fiscal year exclusive of liabilities outstanding July 1, 1889		2,460.41

PROVEMENT OF THE MISSISSIPPI RIVER AT NATCHEZ AND VIDALIA, MISSISSIPPI AND LOUISIANA.

No work has been done in this vicinity, owing to the lack of funds.

The approved project contemplates the protection of the caving banks, by means submerged sloping spurs, placed at intervals yet to be determined, but which are umed for the sake of estimate to be about 1,000 feet; the estimated cost of this rk is $600,000.

To prevent the flow of water across the neck of land between Giles and Cowpen ads, and the possible destruction of the harbors of Natchez and Vidalia by a cut-off, s proposed to construct a levee at an estimated cost of $100,000. This makes the al cost $700,000.

Much alarm has been felt by people living at Natchez during the recent high water regard to this threatened cut-off, which they believe is imminent. It is impossible make an examination of this locality at present in order to determine how great s danger really is. There is a small balance of about $700 now in hand from former propriations for this work, which will be utilized when the river falls to a suitable ge in making survey of this locality.

The amount that could be profitably expended upon this work during the fiscal ar ending June 30, 1892, is $250,000, which will be used for the purchase of the nec ary plant, the construction of the levee, and the commencement of the dike work.

IMPROVING MISSISSIPPI RIVER AT NATCHEZ AND VIDALIA.

Money statement.

ly 1, 1889, amount available	$700.65
ly 1, 1890, amount expended during fiscal year, exclusive of liabilities outstanding July 1, 1889	25.00
ly 1, 1890, balance available	675.65
Amount (estimated) required for completion of existing project	700,000.00
Amount that can be profitably expended in fiscal year ending June 30, 1892	250,000.00

Submitted in compliance with requirements of sections 2 of river and harbor acts of 1866 and 1867.

List of civil engineers employed on works of improvement in charge of Capt. Kingman, Corps of Engineers, during the fiscal year ending June 30, 1890, under river and harbor appropriation acts of August, 1886, and August, 1888.

Name and residence.	Time employed.	Compensation.	Where employed.	Work on which e.
	Mos. Days.	*Per month.*		
H. S. Douglas, New Orleans..	9 11	$175	New Orleans.....	New Orleans Har.
Do.....	2 19	175	Levees on Tensas Front.	Protection of leve.
W. G. Price, Simmsport, La..	8 9½	175	Simmsport, La....	Rectification of Atchafalaya ri.
Do.....	1 22	175	Bayou Plaquemine.	Improving Bayou mine, Louisiana
Do.....	1 7	175	Morganza Levee..	Protection of leve.
Do.....	2 1½	175	Simmsport, La....	Discharge observa.
John Ewens, Simmsport, La .	2 23	150	....do	Rectification of Atchafalaya ri.
Do.....	2 24	150	Bayou Plaquemine.	Improving Bayou mine, Louisiana
W. J. Hardee, Point Pleasant, La.	8 5	150	Levees, Tensas Front.	Hard Times-Wilso.
Do.....	1	150	....do	Protection of leve.
Do.....	2	150	Survey, examination, and inspection.	Survey, examinat. spection.

Approximate value of plant belonging to the United States and used upon the ... ment of Mississippi River, fourth district.

Class of property.	Approximate value June 30, 1890.	Class of property.	Ap va
Steamer *General Newton*.....	$12,000	One floating store-house.....	
Steam-tug *Comstock*.....	7,000	Fourteen row-boats	
Steam-tug *Tilda* (almost totally destroyed by fire May 8, 1890).....		Tools and appliances	
	3,000	Office furniture.....	
Steam-launch *Ruby*.....	3,500	Surveying instruments.....	
Steam-launch *Alaska*.....	3,500	Drawing instruments	
One dredge-boat (Menge patent)....	10,000	Railway cars and track.....	
Four dump-scows.....	10,000	Miscellaneous: rock, lumber, etc..	
Five quarter-boats	12,000		
Twenty-nine barges	46,500	Total	

REPORT OF MR. H. S. DOUGLAS, ASSISTANT ENGINEER.

NEW ORLEANS, LA., *May* 31, ...

CAPTAIN: I have the honor to submit the following report on construction ... and protection of levees, Tensas Front, fourth district, from June 1, 1889, to ... 1890:

At date of last report but little work was in progress on levees. The Hard ... Wilson Levee was under construction, being about three-fourths completed. ... was prosecuted until February 7, 1890, when the levee was reported completed. ... inspected and received February 12, 1890. This levee contains the greatest ... of cubic yards of earth of any levee yet undertaken by the United States. ... tents being 710,163.17 cubic yards, and, including enlargement of old levee. ... miles long. A portion of the levee was built on a ridge between two lakes ... ridge was broken at one point by a bayou or channel connecting the two lakes ... locality was known as the "Gar Hole." The line of embankment crossed this ... and some difficulty was anticipated on account of defective foundation into ... the levee might sink. To obviate this, however, two side levees were built ... the "Gar Hole," inclosing the space for the base of the levee proper. The sp... then pumped dry, and the logs, fallen trees, etc., removed. Then two muck ... were cut, the depth of each being sufficient to reach hard ground. The e... ment was then built in the customary way. As it was feared that there wou... bodily sinking of the levee at this point, the earth of which it was built was ... in excavation instead of in embankment. With this exception there were no ... features in the construction of the Hard Times-Wilson Levee.

the latter part of January, 1890, the rapid caving of the river bank at Point sant threatened to breach the levee at that point and flank the Hard Times-Wilson ee. A piece of new levee was authorized at this place, and its construction com-ced in February. But little progress has been made, owing principally to the ht of the river which filled the ground with seep water.

ıring November, December, and January an assistant was sent into the field to a line of levels over all the United States levees in the district to ascertain posi-ly their condition. The result was generally favorable, the only levees which ıired any repairs being that portion of the Shipps Bayou to Hard Times Levee sing the bed of Lake St. Joseph, some portions of Evergreen, and the Kempe ee.

ıe work being considered necessary arrangements were made for the requisite s and labor. Work on Shipps Bayou to Hard Times Levee was commenced Feb-y 22 and completed March 27. On Kempe operations were commenced February ›ut have not yet been entirely completed, owing to the high stage of the river, ch cut off the supply of earth. On Evergreen nothing has yet been done in the ' of permanent repairs.

n February 12, when the final line of levels was run over the Hard Times-Wilson ee the river had risen to 44.8 feet on the Vicksburg gauge, and was against the ıe for its full length. Reinforced by heavy rains in the valleys of the Mississippi Ohio the river continued to rise, and on March 12 had reached 47.4 on the Vicks-g gauge. This properly brings me to a report on the

PROTECTION OF LEVEES DURING HIGH WATER OF 1890.

n March 12, 1890, I received orders from you to proceed from New Orleans to the ıes on Tensas Front, for the purpose of holding them, if possible, against the ex-›rdinary flood which was even then straining the line and threatening disaster.

ccordingly, on March 13, I left on the steamer *General Newton* with a barge in tow. ı barge was loaded with 50,000 sacks, 50,000 feet of lumber, tarpaulins, chains, twine, ls, etc. On the way up we stopped at the Government fleet near Simmsport where e wheelbarrows and shovels were taken aboard. Although the boat, with a double w, was run night and day, owing to stormy weather and breaking of machinery did not arrive on the Tensas Front until the afternoon of March 16.

ı going up numerous stops were made for the purpose of ascertaining the condition he various levees, and if assistance was needed. Word was received that the Point asant Levee was in a dangerous condition and sacks were needed. We arrived 'oint Pleasant on the morning of the 18th, and found a large force at work and levee temporarily secured.

y this time, owing to the running off of a heavy local rainfall and the breaking everal levees above on the Tensas and Yazoo fronts, the river had commenced to ine. It was known, however, that this decline was but a temporary relief and ; the "Yazoo return wave" would have the same effect as in 1884, of putting the ır to a much higher stage than the one that had passed.

nowing this, the most active and energetic work was at once undertaken all along line. All known weak places were strengthened and arrangements made to con-trate forces and materials at any threatened points.

he line of levees which you assigned to me extended from opposite Warrenton, ›.. to Fairview, La., a distance by the levees of about 125 miles. Of this long tch there was but a very small proportion that did not require work of some kind :ts maintenance, and at times it was impossible for me to get over the line to in-:t and direct work as rapidly as I desired.

he river continued to fall until April 2, the total fall at Vicksburg being 1.5 feet, Joseph 1.65 feet, and at Natchez 1.5 feet. Another rise from the Ohio, augmented › rise from the Arkansas, passed the foot of the Yazoo Basin at the time the "re-ı wave" was pouring into the river.

n April 3 the river commenced rising at Vicksburg and continued until it had hed 49.1 feet on April 24, 0.1 foot above the flood of 1884. In general terms it may aid that, so far as the fourth district is concerned, the flood of 1890 culminated on il 23 and 24, at the latter end of a wind-storm of three days' duration. On April he St. Joseph gauge read 45.1 feet, 0.2 foot above 1884, and on April 23 the Natchez ge 48.6 feet, 1.2 feet above 1884. There were a number of local heights which be noted later. The extraordinary height attained on April 23 and 24 was owing he discharge of the tremendous rainfall in the basins of the Big Black, Bayou re, and Cole's Creek, all flowing into the Mississippi between Vicksburg and chez.

etween April 22 and 24 nearly all the crevasses on the Tensas Front and Atchafa-ı Front occurred, and the rather extraordinary feature of a fall traveling up-stream ı noted. On the 24th, at 11.30 a. m., private observers at Natchez reported 4

inches fall; at Hole-in-the-Wall, at 4.30 p. m., 2½ inches; at Kempe, at 6.4[illegible] inches; at St. Joseph, at 9 p. m., 1 inch, and no fall at Hard Times or Point [illegible] on the morning of the 25th, if anything a slight rise.

The number of crevasses on the Tensas Front, history, width, depth, and d[illegible] have already been made the subject of a previous report.

The following is a general description of the work done on the several l[illegible] protection during the flood of 1890, their condition, and such other inform[illegible] could be obtained:

Bedford Levee.—Head of district; is an ante-bellum levee of strong secti[illegible] work was necessary.

Diamond Island Levee.—New levee built by State in 1888–'89, extending fr[illegible] ford Levee to Bayou Videl. No work was necessary, but it was guarded by t[illegible] authorities.

Bayou Videl Levee.—On west bank of bayou from Diamond Island Levee t[illegible] Palmyra. No work was done but the levee is generally very scant in sect[illegible] was a source of considerable anxiety.

Palmyra Levee.—I have given this name to the long line of embankment ex[illegible] around the bank of Lake Palmyra from Bayou Videl to Point Pleasant. The[illegible] portion of this line is old levee of very strong section. Some work was nece[illegible] the way of raising at New Carthage, at Woodlawn, and Somerset. A small s[illegible] ($106) was expended on this levee for labor by the United States. Some w[illegible] done and paid for by the local authorities.

Point Pleasant Levee.—From Lake Palmyra to Hard Times-Wilson. This le[illegible] built and enlarged by the United States in 1882, 1883, 1884, and 1885. It[illegible] in section at a few places, is generally lacking in height, is full of cray-fish be[illegible] has decided tendency to slough. It was a constant source of danger, troub[illegible] expense during the flood. As early as March 15, an extensive slough occurre[illegible] Turner Place. This was secured by the United States at a cost of $1,096. Fr[illegible] 9 to 19, 1,000 sacks were placed on the levee to repair and prevent wave-wa[illegible] April 20, another slough occurred near Bland's store, which was secured a[illegible] levee was raised from 1 to 1½ feet for a length of 450 feet. On the night of A[illegible] the old slough on the Turner Place caved in half way, the crown of the le[illegible] the land slope let down for 50 feet above and 140 feet below, making the sloug[illegible] 250 feet in length. The earth used to repair the injury had to be wheeled in[illegible] to 1,000 feet, the greater portion about 700 feet. Three thousand five hundr[illegible] were used in addition to earth wheeled in. These sacks were filled about [illegible] from the levee, wheeled onto a flat-boat and boated in front of the sloug[illegible] they were dumped overboard to form a sort of a retaining-wall for the ne[illegible] wheeled in. The cost of this work was $1,148.80, making, with the $1,096 pr[illegible] mentioned, $2,240.80 expanded on this levee by the United States. On the lo[illegible] of the line the levee was raised by the local authorities for a distance of abo[illegible] feet. This whole line should be raised, enlarged, and the numerous cray-fis[illegible] repaired. It is far from being safe.

Hard Times-Wilson is a new levee built by the United States and more fully de[illegible] in the beginning of this report. It extends from Point Pleasant to the United Shipps Bayou to Hard Times Levee. Although this levee gave considerable t[illegible] it was to be expected on account of the newness of the embankment, its exte[illegible] height. It is only surprising that it did not give away, considering that w[illegible] month after its completion it was exposed to such an extraordinary flood. [illegible] nowhere lacking in height and no raising was necessary. The only weakn[illegible] sloughing and injury from wave-wash where the fresh earth was exposed. On [illegible] 27, a slight slough occurred near the "Gar Hole." It was repaired at a cost of $[illegible] This slough recommenced on April 2, and it was again repaired. From Apr[illegible] 19, 2,000 sacks were placed in the levee along Marshall Ridge to repair and [illegible] wave-wash. From April 18 to 29, the levee sloughed at eight different places[illegible] was only by hard work that a break was prevented. Four of these sloughs o[illegible] in a distance of 1,500 feet. The rains had filled up the swamps on the land s[illegible] in some cases it was necessary to wheel in the top of the levee itself. Fortu[illegible] the levee had ample height, otherwise this would not have been possible. [illegible] the heavy rain of April 21, 22, and 23, the slough near the "Gar Hole" again[illegible] and the top of the levee had to be used to secure it. About 3,000 sacks were [illegible] the same manner as at Point Pleasant. The top of the levee was used to rep[illegible] sloughs for a distance of 2,200 feet, the cut being from 1 to 3 feet in depth, t[illegible] leaving 1½ feet of levee above the water at its highest stage. There were [illegible] number of weak points, in addition to those mentioned, but they were not wor[illegible] as the danger was not imminent. They should undoubtedly be repaired before [illegible] flood. Along the Marshall Ridge where the levee is composed of sand, it has [illegible] been destroyed by rain and wave wash. It is in a very dangerous condition[illegible] 2,200 feet of crown that was wheeled into the sloughs should by all means be re[illegible]

he cost of the protection work since March 31 was $1,640.50; previous to that date 78.50; total, $2,219.

Shipp's Bayou to Hard Times Levee, or as now known, "Hard Times Levee," was uilt by the United States in 1882, 1883, 1884, and 1885. About one-half of this line as been thrown out by the construction of the new *Hard Times-Wilson*. The portion ow in service connects the latter levee with Evergreen. It crosses the lower end f Lake St. Joseph and is without doubt, from a financial stand-point, the most impor- ant levee in the fourth district. It was located by myself in 1882, and is as far back om the river as a practicable crossing of the lake could be found. For a distance of 800 et this has been a constant source of trouble and expense on account of the embank- ent settling bodily into the lake bed. Every year since its apparent completion in 885 it has been raised by the local authorities or by the United States. During the resent flood the crown of the levee was only 0.8 foot above the surface. Should a reak occur and the usual deep hole be scoured out on the line of the levee it would ot be practicable to again dike the lake, and the result would be the abandonment of he Hard Times, Hard Times-Wilson, and Point Pleasant levees, worth in round num- ers about $300,000. In addition to this an entirely new line of levee would have to e built encircling Lake St. Joseph on the west bank and joining the Lake Palmyra evee in the vicinity of Ashwood. Knowing this, this short piece of heavy levee in he bed of Lake St. Joseph was a source of the greatest solicitude. I believe that the ettling still continued and was afraid to place much additional weight on top. All hat was done here was to fill and place 200 sacks on the lowest point to prevent the ater running over. This cost $32.50. A small slough occurred on the lighter portion f the line out of the lake bed, and this was repaired at a cost of $148.25; total $180.75.

The flood of 1890 exceeded that of 1884 by 0.25 foot at Hard Times Landing; 1884 vas 0.5 foot above 1882 at that point.

Evergreen Levee connects Hard Times with Hardscrabble Levee. The major portion f this levee was built by the United States in 1885. It was found to be low at several oints, but showed no signs of weakness. During the height of the flood some rais- ng was done by the force engaged on Hardscrabble. No separate account of expenses vas kept.

Hardscrabble Levee.—This levee was completed by the United States in 1885, and for ts height and section is a remarkably good levee. It was generally overtopped by he flood and was raised by throwing up a narrow ridge of earth and sacks on the dge of the river-crown, for a distance of about 4 miles. As the rain had filled up the wamp, the land crown of the levee is now in very bad shape for about 4 miles, and hould be raised and repaired before another flood. The cost of protection was 1,806.77.

Bondurant Levee is a continuation of Hardscrabble and was completed by the United States in 1883. Since that time, owing to the rapid caving of the bank, a new run- around, or horse-shoe, to close some gap has been built almost every year, either by the United States or local authorities. But little of the original Bondurant remains. This evee gave a great deal of trouble, was low, lacking in section, exposed to wave wash, and sloughed badly in two places. Nothing but hard and energetic work and the liberal use of sacks and lumber prevented a break. Prior to my arrival a great amount of work had been done and paid for by the local authorities. The front of the levee had been sacked, the line had been raised, the sloughs repaired, and with a falling river it was secure. The second rise necessitated additional work, which was done and paid for by the United States at a cost of $1,102. Ten thousand feet of lumber and 4,000 sacks were used. A new levee is now being built by the local authorities be- hind the most dangerous portion.

From Bondurant's to St. Joseph, about 4 miles, is an old levee built many years ago. There were several cray-fish holes and sand boils which were repaired by the local authorities. At the town of St. Joseph the flood of 1890 exceeded that of 1884 by 0.2 foot, and 1882 by 0.6 foot.

From St. Joseph to Kempe, a distance of about 9 miles, there are two large levees, the Marshall and Lee, both of which had to be raised, the latter very extensively. The work was done by the local authorities, the United States furnishing 5,000 sacks.

Kempe Levee.—The existing one is the second built by the United States since 1882, and it is about the heaviest piece of embankment in the district, ranging from 16 to 22 feet in height for a distance of 3 miles. The present levee was completed and re- ceived in February, 1889, and, considering its newness, stood the flood remarkably well. The weakness was confined to about 500 feet of the line where the contractors had struck a sand pit and built the embankment of almost pure sharp sand. The levee at this point was about 22 feet high. On March 23, the first signs of weakness were observed. A stream of water of considerable size broke out of the ground about 10 feet from the base of the levee on the land side. A double bulkhead of lumber was built around it and the space between filled in with tamped clay. This eventually showed signs of weakness and the bulkhead was re-enforced with 1,600 sacks. This closed the hole and it gave no further trouble. There was a force at work on this levee

raising it and bringing the crown to a uniform grade. Previous experience o levee in building it by hired labor had taught me that during high water it wa a matter of a short time when the swamp back of the levee would be deeply overf from back water and rain, when no earth could be obtained.

I went to Simmsport and towed up one of the light barges belonging to the U States for the purpose of boating earth from the old levees when the before-men contingency should arise. The barge arrived on the work March 31. Withou believe the Kempe Levee would have given way. On April 8, while inspectin the levee, I discovered that the sandy portion was becoming very soft on the side. April 10, another inspection was made and the softness had increased, streams of water passing through. Work was absolutely necessary, and opera to strengthen the levee were commenced the following day. My next visit wa Sunday the 13th, when I found no force at work, it not being customary amon negroes to work on Saturday afternoon or Sunday. The danger was immine there was a large portion of the levee that had become semi-liquid and a break liable to occur at any moment. The citizens up to this time had not appreciated danger and had not sent their laborers to the work. It became necessary for notify them of what was threatened, that a saturated bank of sand was all that between them and overflow. After this no further trouble was experienced in ing labor at all times. Long before this the back water had cut off the supp earth on the land side and all the material used to secure this sandy portion o levee had to be boated. The source of supply was the tops of old abandoned in the vicinity, the barge being pulled through the timber for about half a mi hand. On April 28 it became necessary to engage a tow-boat and tow the barg miles up the river in order to get earth. By May 1, the weak point in the new K Levee had been secured, but in the mean while the old Kempe above had commen to slough, and the barge was transferred to that point and all weak places wer paired. All work was suspended May 8, and the barge was returned to Simmsport. cost of stopping the hole underneath the levee was $375.65; of securing sandy po of new levee and sloughs in old levee, $2,930.35. As about 6,615 cubic yards of e was placed in the levee the cost per cubic yard was 44¼ cents per yard, which, the earth was boated, I consider remarkably cheap. This is the first time within last twenty years that any of the numerous levees built in the Kempe Bend ever held an extraordinary flood. The greater portion of the work done has advantage of being permanent. The raising of the levee should be completed some little work done on the known weak places at low water to make the line sonable secure.

At Kempe the flood of 1890 0.31 foot below 1884.

Kempe to L'Argent, about 8 miles, stood the flood without showing any weakn importance. Some little work was done by the local authorities for precautio reasons.

At Waterproof the flood of 1890 was 0.6 foot below 1884.

L'Argent to Rifle Point.—This is a general name for about 9 miles of the worst le in the district, on which more money was spent and more material used than any o place. The local names for the line were in order L'Argent, Aquaska, Monona, H in-the-Wall, Delhi, Canebrake, Shamrock, and Vaucluse, and except Hole-in-the W was built in 1856. It had every element of weakness that I ever heard of in a le was too low, lacked base, lacked crown, was exposed to wave wash, riddled with c fish holes, had large standing trees growing in the slopes, old rotton stumps in same, sloughed, and was rotton and worthless in every respect. Work for its pro tion was found necessary as early as January 28 and continued until April 4 under direction of the fifth Louisiana levee board. On April 5 the United States assum charge of the line and the greater portion of the work was done and required as flood reached its height on April 23. The whole line was generally overtopped fr 0.5 to 2.5 feet, and was raised principally with sacks, and in several places none of original levee could be seen, it being entirely covered with sacks. There were fi teen sloughs aggregating 957 feet in length, some of them the most obstinate dangerous I have ever had to deal with. There were two large dikes on the l across Bayou L'Argent and the lower end of Lake St. John, and both of them slough At Lake St. John the dike was overtopped 1.5 feet and a crevasse nearly occurr The seepage water through the levee had overflowed the lands in the vicinity rend ing difficult to get earth with which to fill sacks, etc. Large ditches were dug drain this water off, some of them as much as 1½ miles long. This drainage was great benefit and assisted materially in the holding of the levee. It would be tedious to describe all that was done in detail. Work was practically continu over the whole 9 miles. Over 60,000 sacks were used, 29,750 of which were furnish by the United States and the balance by local authorities. About 4 miles of the le was overtopped by the flood, in some places as much as 2.5 feet. The hight of t flood at L'Argent exceeded that of 1882 by 2.58 feet and that of 1884 by 1.66 fe The cost of the work to the United States was $6,684.

Rifle Point Levee from Rifle Point to Grassmere, about 2 miles.—Prior to my arrival some work had been done by the fifth Louisiana levee board in the way of temporarily raising low places. At the height of the flood the levee was overtopped and was raised with earth for one-half mile. A few hundred sacks were used and contributed by the owner of the plantation. The cost of the work was $112.50.

Grassmere Levee connects Rifle Point with the United States Lake Concordia and is about 1 mile long. It is a very old levee and in its time was very strong, having a 20-foot crown. Its present weakness is lack of height. Before my arrival it had been raised temporarily for about 2,000 feet by the fifth Louisiana levee board. This temporary work was afterwards raised and strengthened by the United States. The height to which the levee was overtopped was the thickness of four sacks laid on the flat, or about 1.75 feet. At this locality the flood of 1890 exceeded that of 1882 by 1.9 feet and 1884 by 1.4 feet. The cost of the protection work was $221.90.

Lake Concordia Levee was built by the United States in 1882–'83. It is a long line of generally light embankment encircling Lake Concordia for a distance of about 18 miles. The upper end is at Good Hope Landing and the lower near the town of Vidalia. The flood of 1884 breached this levee at numerous points. These gaps were closed and the line raised about 2 feet and enlarged for about 3 miles by the United States in 1885. This raising and enlarging were afterwards completed by local authorities over the whole line, I believe. The flood of 1890 has proven that it must be still further raised and enlarged to be a reasonably safe levee. Before my arrival protection work had been done by the fifth Louisiana levee board, some 12,400 sacks being used to raise the levee and repair wave-wash. As in the case of L'Argent to Rifle Point, it would be tedious to describe the protection work done in detail. With the exception of one mile on the upper end work was almost continuous. Although the levee was only overtopped for a little over a mile it was awash for three times that distance. There were eight sloughs in the line, aggregating 280 feet in length, and the levee was badly wave-washed for 6½ miles. On April 22 the levee broke about 150 feet from the large crevasse of 1884. The break was one of those accidents that will occur as long as levees exist. No warning was given, and a few minutes before the break occurred persons had passed over the levee and noticed no signs of weakness. Full particulars in reference to this crevasse have been given in a previous report. The cost of the protection work done on this levee was $2,143.70; 16,000 sacks and 30,000 feet of lumber were furnished.

Palto Alto Levee, about one-half mile long, connecting Lake Concordia with the town of Vidalia, required practically no work.

Town of Vidalia Levee, about 1 mile long, is generally a very insignificant affair. In some places there was practically no levee. At the height of the flood the citizens appealed for assistance and 2,000 sacks were furnished them and labor to the extent of about $125.30. The work done was successful. At this point the flood of 1890 exceeded that of 1882 by 0.7 foot and 1884 by 1.1 feet.

Arnauldia Levee, about 1½ miles long, runs from Vidalia to Whitehall. A considerable portion of this levee was fine sand, and after the Concordia Crevasse it was allowed to wash away and cause a crevasse, which, however, was a small affair. The levee was badly exposed to wave-wash, and had been strengthened by facing with sacks for about one-half mile. The cost of this work was $197.50.

Whitehall Levee, about 2 miles long, from Arnauldia to Lucerna. There was a low place, which was raised, at a cost of $4.

Scotland and St. Genevieve Levees, about 2½ miles long, required but little work. Some repairs had been made by the fifth Louisiana levee board prior to my arrival. The United States expended $11.00 in raising two low places that had been previously worked on by the levee board.

Forest, Moro, and Morville Levees, about 4½ miles long. These are all small levees which high water seldom reaches. The protection work done was mostly to prevent wave-wash and raise a few low places. The residents did most of the work and furnished the material. The levee board had done some work prior to my arrival. The United States expended $119 for labor on protection of these levees.

Henderson-Ashley Levee extends from Morville to the United States Greens to Fairview Levee, about 5 miles in length, and is for a considerable distance 15 feet high. It is about thirty years old, and, like most of these old levees, very strong in section. Lack of height is its only weakness, and this, unfortunately, was a fatal one. Prior to my arrival some of the low places had been raised by the levee board. At the top of the flood the line was overtopped an average of 1 foot for a distance of 4 miles. I had had a small levee built on the edge of the river crown of the main levee, and a strong fight was made on this. The Concordia Crevasse demoralized the force, and one of the numerous breaks in the small levee on top was allowed to get too much of a start. The water running over the top of the old levee caused a crevasse which is fully described in a previous report. The cost of the protection work was $513.75. About 8,000 feet B. M. lumber and 4,000 sacks were used, of which 5,500 feet of lumber and 1,500 sacks were furnished by the United States.

Greens to Fair View and Deer Park Levees.—This is practically one line, abo miles long, built by the United States. The original Greens to Fairview wa pleted in 1884, and Deer Park was built in 1888 to close a gap in the main line c by caving of the river bank. The line, considering its length, required but little the principal element of weakness being lack of height. It was extensively topped by the flood. Before my arrival work had been done by the levee b Some rumored dishonest work on the Deer Park Levee had been repaired, and a hole underneath the levee on the Fish Pond place had been closed. The upper of the line passes through cultivated lands, and on this portion there were s incipient sloughs, some wave-wash, and the levee was overtopped for 1¼ miles was raised with sacks and lumber. The lower end of the line passes through Glasscock Swamp for a distance of 3½ miles, the embankment ranging from 12 feet high. It was and is an excellent piece of work, although scarcity of m caused it to be built with small section, the slopes being only 2 and 3 to 1 and crown 8 feet. At the height of the flood it was overtopped for over a mile, and raised by building up the edge of the river crown, using the edge of the land cr for that purpose. At the lower end in the Fairview field the levee was washed siderably by the waves, and should be repaired before another flood. The crow the Glasscock Swamp will have to be repaired and this portion of the line should cleared of the dense growth of timber which has grown up on the slopes of the le In the open fields above the levee should be raised where low. An entirely n levee will be necessary at Deer Park, as the present line will cave in when the r falls. The cost of the protection work was $572.32. Four thousand feet B. M. l ber and 2,500 sacks were furnished by the United States. No accurate data as to comparative height of the flood of 1890 were obtainable, but it is claimed to have 1.66 feet higher than 1882. I believe this to be nearly correct, as the established gra of the levee was only 1 foot above 1882.

Fairview is practically the lower end of the levee system on the Tensas Fr The levee board have continued the system about 2 miles farther, and below t there are gaps, private levees or isolated pieces of old public levees.

The term "slough" has been frequently used in this report in describing a cer kind of weakness in some of the levees. A slough is the giving away of the land slop the levee, caused by the saturation of the embankment or its foundation, or perh both. The first indication of a slough is generally small streams of water runn through the levee. Next a crack commences to open on the slope, and a large se circular mass of earth slips down, leaving the slope nearly vertical. Sloughing progressive, and if something is not done it eventually goes through the levee an crevasse is made. The method used in cases of this kind was really nothing m than to build the levee out towards the river faster than the slough progressed fr the land side. In some cases plain earth was wheeled in; in others sacks were u and sometimes both, the sacks being placed so as to form a retaining-wall and foun tion for the earth. In one case, Point Pleasant, nearly all of the original levee sloughed away and a new levee built on the river side as described. There is a the that in dumping loose earth on the river slope it has the same result, and answers same purpose as putting sawdust under a leaky barge—that is, of stopping the leak However true this may be, none of the sloughs that came under my observation w secured until virtually a new levee had been built in front.

Where it was necessary to raise a levee with sacks the method used by me was place the sacks end to end and slightly lapping each other, parallel with the line the levee. If necessary this was re-enforced in the rear by a second line, breaki joints with the first. If a second tier in height was required they were laid in t same way, very much in the style of a brick wall, only there were no headers. L in this way, with some earth scattered between by way of mortar, they seldom leak

I think that so far as the fourth district is concerned the flood of 1890 may considered the most extraordinary of which we have any record. At such points it did not exceed in height it exceeded in duration. At Vicksburg tradition mak the flood of 1862 considerably higher than that of 1890, but as the latter flood wa above the danger-line on January 30, and on May 31 it is still above it, a period 121 days, I think 1890 certainly exceeds in duration.

Starting on January 30, when the river reached 41 feet on the Vicksburg gauge have compiled the following data, showing duration of flood:

Above 41 feet, 121 days, and is still above; above 42 feet, 119 days, February 1 May 30; above 43 feet, 112 days, February 4 to May 26; above 44 feet, 105 days, Fe ruary 8 to May 23; above 45 feet, 96 days, February 14 to May 20; above 46 feet, days, February 26 to May 17, above 47 feet, 50 days, March 11 to March 24, April to May 12; above 48 feet, 22 days, April 15 to May 6; above 49 feet, 3 days, April to April 26.

At Natchez the flood of 1890 on April 23 reached 48.60. The highest flood previous recorded was in 1815, when the gauge reached the same height. As it is scarce

probable that there was anything approaching a line of levees in 1815, it does not appear reasonable to believe that the levees have raised the flood at this point.

As previously stated, the line which you assigned to me was 125 miles long, and in this stretch, according to the general impression, there are some of the worst levees to hold against a flood that are to be found anywhere on the Mississippi River. Considering the magnitude of the flood, it is gratifying to report that but three crevasses occurred in the distance of 125 miles, and one of these of no importance. The aggregate width of all three was 2,165 feet, or less than half a mile.

In conclusion I would state that while the employés of the Government did all they could, their efforts would have been of no avail had it not been for the energy and public spirit of the residents themselves. If assistance is due to those who help themselves, then these people are fully entitled to all the aid that can be given them.

I left New Orleans March 13 and returned May 15, being absent sixty-three days.

Accompanying this are the reports of Mr. William Garvin, overseer; Mr. V. Maxcy Markoe, inspector, and Mr. L. P. Ault, subinspector.

Very respectfully, your obedient servant,

H. S. DOUGLAS,
Assistant Engineer.

Capt. DAN. C. KINGMAN,
Corps of Engineers.

REPORT OF MR. WILLIAM GARVIN, OVERSEER.

NEW ORLEANS, LA., *May* 19, 1890.

SIR: I have the honor to report as follows: I arrived at Point Pleasant on April 2 and in accordance with your verbal instructions assumed charge as inspector of the Evergreen, Hard Times-Wilson, and Point Pleasant levees on April 3.

I found a force of men at work repairing slough at the Gar Hole on the Hard Times-Wilson Levee. This place was protected by the usual method; increasing width of levee, building out on river side. At this point it was difficult to obtain earth, the land side being almost entirely submerged by water from White Oak Lake. The material used was mud dug from the bank of the lake and the wheel was a distance of from 400 to 800 feet. To use this material all the timber felled on the right of way had to be cleared off, which added very much to the cost of the work.

From April 9 to 19 about 1,000 sacks were placed on Point Pleasant and 2,000 on Hard Times-Wilson Levee, along Marshall Ridge, to protect them from wave-wash. Along this ridge the levee is built principally of sand and has been badly damaged by rain and wave-wash. In many places the crown is not more than 2 or 3 feet in width and the land side has been washed out to a slope of about 1 to 1.

From April 18 to 29 work was done on eight different sloughs on Hard Times-Wilson Levee, four of them within a distance of 1,500 feet and about 1 mile above Hard Times Landing. For these sufficient earth was found on the lake bank, but it was very wet and difficult to handle. One about 3,000 feet below Gar Hole had lake water at base of levee and I was forced to cut top of levee to protect it. One-half of the crown on the land side was cut 18 inches deep for a distance of about 1,000 feet. For the two about 400 and 900 feet below Gar Hole the earth was taken from the bank of White Oak Lake.

During the heavy rains the old slough at Gar Hole commenced washing and going down very fast and increasing in length. It was covered with old tarpaulins to protect it from rain-wash. All the earth on Lake bank had been used during previous work and the top of levee was taken to protect this place The entire crown was cut from 1 to 3 feet in depth for a distance of about 1,200 feet, letting the levee stand 18 inches above the water at the highest gauge of the river during the present flood. Three thousand sacks were used on this work. They were dumped from a boat at base of levee to act as footing or brace for earth dumped from top of levee.

On April 20 a slough occurred about 400 feet above Bland's Store on Lloyd Place. At this point earth was easily obtained near base of levee.

On April 22 the Point Pleasant levee was raised or topped at four different places from Bland's Store to Turner Place. This work was from 1 foot to 18 inches in height, and all places included about 450 feet in length.

On night of the 22d the old slough on Turner's Place, Point Pleasant Levee, caved in half way; the crown and slope went in for 50 feet above and 140 feet below, making the slough about 250 feet in length. The earth used was wheeled a distance of from 400 to 1,000 feet, the greater portion about 700 feet. Three thousand five hundred sacks were used at this slough; they were filled about 400 feet from levee, wheeled into a boat, then taken to the slough and dumped at base of levee to act as toe for earth.

All sloughs were protected by the usual method, increasing width of levee by

building out on river side and allowing earth to take its natural slope, except at Gr Hole and Turner Place sloughs, where a line of sacks were used as footing or toe f loose earth.

On the Hard Times-Wilson Levee there is a weak place about 3,500 feet below Gr Hole. This place showed signs of sloughing and had several small streams flowi from the base of levee during this flood. During high water this place could not b strengthened without boating earth or using top of levee, which does not exceed feet above the surface at high water.

At the head of the Styx, a deep slough on the Point Pleasant Levee, several considerable streams were flowing through the levee. At the Willow Slough, abo Bland's store, there are several bad sand-boils, and the apron crossing the slough ha caved in for 8 or 10 feet in width by 40 in length. These places were a source of grea anxiety during the present flood. They should be repaired during low water, as i would be very difficult and expensive to repair them properly during a flood.

Very respectfully,

WILLIAM GARVIN,
Overseer.

Mr. H. S. DOUGLAS,
Assistant Engineer.

REPORT OF MR. V. MAXCY MARKOE, INSPECTOR.

NEW ORLEANS, LA., *May* 17, 1890.

SIR: I have the honor to report that on March 13, 1890, a considerable stream of water was discovered coming up out of the ground about 10 feet from the bottom of the slope on the land side of the United States Kempe Levee, supposed to be a crayfish hole. We built a double bulkhead of plank and posts about 3 feet in the clear and 2 feet between the two walls and tamped it with mud. Cost for labor and material, $79.35. It was not strong enough to completely hold the water, and by your orders we re-enforced the outer wall by 1,600 sacks placed like bricks. This accomplished the object at a cost of labor, $296.30. April 10, we discovered that some five consecutive stations at the up-river end of this levee were very weak and that two sloughs had started. As the backwater by this date had entirely submerged the land it was found necessary to get the earth from the abandoned levee about one-half mile toward the river, which we did by hauling a barge by ropes until the levee was stripped to the water's edge. Then it was found necessary to hire a steamer to haul the barge about 1½ miles farther up the river. Cost of steamer, $340. In this way we increased the crown of the levee at these weak places nearly double, with natural slope on the river side, using about 5,590 cubic yards.

In addition we strengthened other small weak places along the old levee above joint with new, using about 1,025 cubic yards. We also placed 865 sacks on three low places. Total cost, $2,930.35, or about 43 cents per cubic yard.

We had much bad weather to contend with, and as hauling the barge through the woods was a slow way the cost looks large even for repair work.

Very respectfully,

V. MAXCY MARKOE.

Mr. H. S. DOUGLAS,
Assistant Engineer.

REPORT OF MR H. P. AULT, INSPECTOR.

CONCORDIA PARISH, LA.

SIR: Pursuant to your instruction I have made a careful tour of the levees in this parish from Bayou L'Argent, the upper boundary, to Fairview, a line of about 65 miles, and herewith submit a report of the work done on same to preserve and protect it during the high water of 1890. In this report I shall speak of the first rise, which took place and reached its maximum height on March 16, 1890, when the gauge read 47 feet at Natchez, Miss.; and the second rise, which reached its highest on April 22, 1890, and the Natchez gauge read 48.60 feet.

The greater bulk of the work was done under and by the instruction of yourself, representing the United States Government, and by Mr. W. F. Ogden and myself, representing the Fifth District Levee Board of Louisiana.

The line of levee known as *L'Argent* to *Rifle Point* was built about the year 1856, except a small portion immediately in front of the "Hole-in-the-wall House," which was built about eight or ten years ago; has never given any trouble, having always been considered perfectly safe until the present flood of 1890. The cause of the

trouble is the Cole's Creek or King's Point cut-off made in 1884, which raised the river level, Mr. Ogden asserts, some 3 feet, and taxed the ingenuity of man to save them.

Work was found necessary on the Monona Levee as early as January 28, 1890, and was kept up continuously until May 1. The levee board used about 10,000 sacks and expended some $1,600 for labor. The United States used about 15,000 sacks, some of which, about 4,000, were paid for by levee board, and no other kind of work was done on this levee, which for its entire distance 1½ (miles) is completely covered, from its inner to the outer base, with sacks. There were no sloughs, but a number of soft spots occurred, and it was overtopped its entire distance from 6 inches to 2½ feet. It is quite a large levee, having from a 4-foot crown 6 feet high to a 6-foot crown and 9 feet high. The almost entire front is exposed to wave wash, and as this spring has been unusually prolific in storms, work was necessary the entire time, and a few of the storms occurring at night, great vigilance was necessary, and as many as two hundred hands were put to work to hold and save it; in fact its preservation is regarded as something pertaining to the miraculous. A great deal of ditching was done to draw off the seep water with excellent effect.

Hole-in-Wall Levee is 1½ miles long, is a large and well-built dike, being in some places 10 feet high. In March it was seriously affected from wave-wash, and some 5,000 sacks were placed upon it by the levee board. Since the United States took charge considerable work was necessary to preserve it; some 5,000 sacks or more were used to prevent wave-wash. There were three sloughs, 47, 25, and 30 feet, respectively, which took some 1,200 sacks, and for about 250 feet it was overtopped; the length of line worked upon was 1 mile.

Delhi Levee is one-half mile long, between 5 and 6 feet high, and considerably worn. About 500 sacks were used upon it by the levee board during the first rise; afterward and during the second rise it was sacked its entire length, some 1,500 or 2,000 sacks having been used by the United States, it being overtopped.

Canebrake Levee is 1¼ miles long, between 5 and 6 feet high, very old and considerably worn. About 800 sacks were used upon it, revetting the crown in low places. The United States used over 2,000 sacks in revetting the crown, which was overtopped for three-fourths of a mile, and about 600 sacks on two sloughs, 50 and 75 feet long.

Shamrock Levee is 1 mile long, average 6 feet high, old, very much worn and narrow, except a very large dike across the lower end of Lake St. John, which has a 16-foot crown and is about 14 feet high. No work was done on this levee except what was done by the United States; was overtopped for three-fourths of a mile, and a slough of 30 feet in the narrow part, upon which 1,500 or 2,000 sacks were used. The large dike across Lake St. John was overtopped and two fearful sloughs took place, aggregating 150 feet. Not many sacks were used upon this levee. Dirt was hauled in scrapers and about 300 yards of earth placed on the outside.

Vaucluse Levee is 1½ miles long, large, well built, and splendidly preserved; has always been considered one of the safest and best levees in this parish. The levee board spent some $4 during the first rise, but during the second rise while in charge of the United States, two immense and terrible sloughs took place, one 260 feet, the other 190 feet long, and some 8,000 sacks were used in strengthening the outer base, making a most excellent and secure job. These sloughs no doubt were caused by the immense locust trees that grew at the outer base, and whose roots penetrated the levee and acted as conduits for the water.

Rifle Point Levee, next adjoining Vaucluse on the south, is about 2 miles long, very strong, substantial, on very high ground, with an immense batture in front. During the first rise the low places were raised by the levee board, being earthwork entirely, at a cost of about $40. During the second rise it was overtopped for over one-half mile, the labor for which was paid by the United States, and amounted to about $115. Some few hundred sacks were used but they were contributed by the owner of place.

Grassmere Levee comes next, about 1 mile in length, built in ante-bellum days; it is an excellent one, well protected by batture not over 7 feet high. It has, or rather had, a crown some 20 feet broad after the King's Point cut-off was made. It was considered below grade, and the parish raised about one-eighth of a mile of it. When the first rise came it ran over in a few places. To prevent it leaking the levee was ploughed in the center and a levee built on its top for nearly one-half mile at a cost of $30 to the levee board. When the second rise came, this work was kept up, but the water became so high and this temporary levee so soft that 3,500 sacks were used to save it. The sacks were ordered and paid for by the levee board; the labor bill, amounting to $225.90, paid by United States on April 21; night work was done. Seven-eighths of a mile was overtopped.

Next in order comes the United States *Lake Concordia Levee*, some 20 miles in length, commencing at Bullitt's Bayou and running along the front of the following places: Grassmere, Pittsfield, Windermere, Weecama, Claremont, Panola, Helena, Concordia, Fletcher, Sycamore, Minorca, Tacony, Arnauldia, Lake Place, and Palo Alto. This levee was finished by the United States in 1885, I believe, after the parish had spent

some $30,000, and I believe the State levee board had expended quite a sum; is a fine levee in some places, in others narrow; no slope and below grade.

Grassmere.—One mile is in fine condition, and no work was necessary during the present water.

Pittsfield has 3 miles front, is a large fine levee and in good condition, except where it crosses a low place in a slough. In January last I found it full of cray-fish holes and considerable water running through. I dug them out and put in 50 sacks filled with earth, which then closed it, but since the second rise a great quantity of water has run through and for a long while the water was muddy. The heavy black land of which it was built only saved it. The entire place should be dug out and the levee rebuilt for at least 400 feet. Ten dollars and the 50 sacks paid for by the parish were all the expense incurred during the first rise. During the second rise there was a small slough which 75 sacks stopped and about 200 more were used in wave-wash. The bill, some $22.35, was paid by the United States.

Windermere has 1¼ miles of levee in good condition, up to grade. No work was done during first rise. During the second rise a slough occurred 80 feet long in which some 250 sacks were used; paid for by the United States.

Claremont has 1 mile front, some of it in very good condition; the major part is poor narrow crown, not enough slope and lack of height. During the first rise some 1,200 sacks were used, at a cost of $60, paid by the levee board to protect it from wave-wash. During the second rise it was wave-washed a quarter of a mile, overtopped a quarter of a mile, and a slough occurred which took some 100 sacks; altogether 2,000 sacks were used, and all the labor was paid for by the United States.

Panola has a mile front and is in as fully a bad condition as Claremont, both levees being built too near the lake shore and the building for secure protection. During the second rise, as near as I can learn, 4,000 sacks were used, and labor was paid for by the United States. It was wave-washed its entire length and overtopped for three-quarters.

Helena (Ferriday Place) has a mile front, built of light sandy soil, and is a succession of bayous and ridges. While seemingly sound and secure, good high crown and slope, it is the most dangerous levee in the parish, for it gives way without a warning and apparent cause, and is sure to catch you unprepared to meet the emergency. A very large crevasse occurred here in 1884 and very near this place another occurred this year, and in a place that had been ridden over just fifteen minutes before, and which then looked to be sound and in no danger whatever. Just the week previous two bad places were discovered, fortunately in time to save them, one a mere hole, which suddenly enlarged and was with great difficulty stopped. In the other the levee gave down in the center of the crown and a stream of water passed through. One fortunate thing about this crevasse was it giving way where it did. It ran down in the washout of 1884 into Bayou Cocodra; thence through the low center of the parish into Red River, and has done very little injury; in fact, it does not overflow the place upon which it broke, and parties living upon Black River claim that it did not cause the water to rise 1 inch. During the first rise some 500 sacks were used and $40 labor bill paid by the levee board. During the second rise, and up to the time of the crevasse, some 2,500 sacks were used to close breaks in levee above referred to.

Concordia and Fletcher.—Have 1 mile front similar to Ferriday Place, but singular to relate, they have not given any trouble. During the first rise 200 sacks were used and $30 paid for labor and ditching the sea water away by levee board. During the second rise they were overtopped some 300 yards, and 500 sacks were used and the labor paid by the United States.

Sycamore, Minorca, and Tacony have 5½ miles of front, the almost entire length of which is affected by wave-wash, and along this line the battle has been continuous since early in February. The north wind has a 4-mile sweep at it, and the frequent gales this spring from that direction have caused lots of work. During the first rise some 8,000 sacks were used, and $600 expended for labor by the levee board. During the second rise about 10,000 sacks and 35,000 feet of plank were used, and an immense labor bill paid by the United States to protect it from wave-wash and overtop. These levees need raising and width. They had a close call and another rise might get them.

Arnauldia and Lake Place are in excellent form and have required no work.

Palo Alto, or what is known as the Punch Bowls, is about half a mile long; a large, fine levee, reaching 9 feet high; was always regarded as perfectly safe, and no material damage was done to it, as it is a better levee to-day than when it was built. Two sloughs occurred at the maximum of the second rise, about 30 feet long each. It was saved by barrow work, and a complete levee was built on the outside of earth. About 400 sacks that belonged to the town of Vidalia were used on the inside to form out slough with excellent success. The labor bill, $125.30, was paid by the United States.

Town of Vidalia is next with 1 mile front, very high, and comparatively no levee

isted when the water came up, having been worn out and torn almost entirely own, the town having escaped overflow except in the years 1862 and 1882; then it ame from the rear. About $300 was spent and 2,500 sacks used by the citizens, who rned out and worked manfully two nights when the levee was expected to give ay, which was built entirely of sacks. Two thousand sacks were furnished and $125 bor bill paid by the United States.

Arnauldia adjoins with 1¼ miles front. The old levee having caved into the river new one was built last fall by the levee board, and for some reason unknown no evee was built in front of the residence and quarters, which I had put up at a cost f $125 when the water first came up. When the second rise came the entire line ad to be worked upon, some 4,000 sacks and $200 being expended by the United tates. When the Ferriday Crevasse occurred they quit work and got their stock over he river into the hills. The levee being neglected gave way and a small crevasse ccurred. The water ran down through Whitehall Lake and through the canals into he interior. Only the low lands on three places were submerged; they are now lanted in cotton, and the water almost ceased to run through the break.

Whitehall is next with 2 miles of levee front. No work was done, except when the water was at its highest. Four dollars was paid for raising a small portion.

Scotland and St. Genevieve, 2½ miles, high front, except in one or two places. Fifteen dollars was spent by the levee board repairing when the first rise came; afterward he United States spent $11.60 in raising some places.

Forest is next, 2 miles, and has a very high front. Some portions having caved off $25 was spent by the levee board in repairing and afterward $47.50 was paid for labor by the United States to save these places. All the cotton and corn planted on this place was saved.

Moro follows and has a front of 1¼ miles and a caving bank. A new levee was built ome two years ago, which withstood the present flood. A portion of the old levee emains near the Morville line, which was badly wave-washed, and $19 paid for its epair by the United States. The sacks, some 300, were furnished by the owner of he place.

Morville, 1 mile. Levee quite low and wave-washed; $25 was paid for repairs by evee board. During second rise $52.50 was paid for laborby the United States. All he material used was furnished by the owner of the place.

Wanniout and Henderson-Ashley Leves is next, 5 miles long. It is considered one of he finest levees in this district, and it is beyond comparison the finest in this Parish; s near 15 feet high, with 25 feet crown, and a slope of 1 in 6, but unfortunately is be- ow grade. When the first rise came the entire line was overtopped. Some 7,000 or ,000 feet of plank, etc., being used, besides 4,000 sacks; also the labor bills, amount- ng to $500, was paid by the United States. Some 2,500 sacks and a lot of lumber was urnished by the owner of these places. When the Ferriday break occurred the man- ger was sent off with the stock to the hills, and the levee not getting the attention t should have got, gave way in a number of places, all of which were closed except ne, which widened so rapidly that it was impossible to save it, and the water is now unning through there 800 feet wide. It is of the lower line of levees, and all of the places below it being already submerged it raised the water inside and will hold the water up on them for a longer period than if it had remained intact.

United States Green's to Fairview consists of Guia Tract, Handy Walton's, Lehman's, Green's, Deer Park, Forest Home, Fish Pond, Ashley, and Glasscock's, about 12 miles ong. Guia Tract, Walton's, and Lehman's are part of the old levee, and gave no trou- ble except at Lehmans, and was overtopped. About 200 sacks were used and labor paid by the United States. No other work was done or necessary.

Greens, one-half mile, in fair condition. Very little work was done on this levee during the first rise. About $15 was paid by parish to repair ruts caused by rains and sinks, and by barrels and boxes being left in the levee by contractors. About 500 sacks were used during the second rise to protect it from wave-wash, which was paid for by the United States.

Deer Park, 1½ miles, is also a fine levee, but I very much fear the greater part of it will cave in when the water falls. But little work was done during the first rise, not over $30 by the levee board for general repairs, but during the second rise 3,000 sacks and 1,500 feet of lumber was used to prevent wave wash and stop two sloughs, each about 20 feet long. The bill for labor and watching paid by the United States amounted to $200.

Forest Home has a mile front; it is in fair condition. During the first rise no money was spent on it. During the second rise it was overtopped its entire length, and 3,000 or 4,000 sacks and 1,000 feet of plank used, and labor bills amounting to $150 paid.

Fish Pond is about half a mile long, high front and small levee. During the first rise a slough occurred in Fish Pond Bayou that cost the levee board $124 to repair for labor and material. During the second rise it was overtopped for about 150 or 200 yards, about 400 sacks being used.

Ashley has a high front 1 mile long, was safe and no work necessary. Glas is a fine levee and large, 17 feet high, 8 feet crown; is built through the swa that name, and is entirely overgrown with briars, willow, cottonwood, and sycam It is very essential for the future preservation of that levee that all of this gr should be cleaned off, so that the sod may have a chance to grow. During the rise the water did not get to the top, and no money was expended thereon. The rise overtopped it for over a mile, and the inner crown was sacrificed to make s on the outer crown, there being a heavy batture in front. No sacks or other rial was used. The bill for labor was $123.75, and was paid by the United S In the Fairview field where it was exposed to wave action the inner base is l washed, and must be repaired to make it safe.

In connection with this report I will state that the parish employed watchmen and night on all dangerous points along the entire front, and have paid out some therefor.

Respectfully submitted.

H. P. AULT,
Inspecto

Mr. H. S. DOUGLAS,
Assistant Engineer.

REPORT OF MR. H. S. DOUGLAS, ASSISTANT ENGINEER.

NEW ORLEANS, LA., *May* 31, 189

CAPTAIN: I have the honor to submit the following report on the work of imp ing the harbor at New Orleans, La., from June 1, 1889, to May 31, 1890:

At date of last report, May 31, 1889, the condition of the work was as follows: work done on spur-dikes in previous years appeared to be in good condition Spur No. 1 of the Greenville Bend system 68,500 square feet of mattress and 1 cubic feet of crib-work had been placed; material for construction to the val about $17,000 was on hand. Three new barges and a quarter-boat had been a to the plant, one of the old barges had been rebuilt, and the tug *Tilda* had b equipped with a new boiler. New crib-ways were being built and general prep tions for the resumption of spur-dike construction were in progress.

On June 14 and 15, 1889, the tug moved the plant from laying-up quarters to Greenville Bend. The river at this time was raising rapidly, but it was known the rise would last but for a short time. The great advantage of commencing at early date will be seen in this report.

GREENVILLE BEND.

On June 22 the construction of cribs for the completion of Spur No. 1, Green Bend, was commenced, and on August 9 the spur was finished. The number of act working days was thirty-seven, twelve days being lost by Sundays, holidays, r and storms. Daily showers and difficulty in handling the brush stored on the ba from the previous season retarded the work. The cribs built and sunk were n bered continuously from those of the previous season, and had the following dim sions:

Crib No. 7	feet..	50 by 110 by 6	Crib No. 11	feet..	32 by 250 b
Crib No. 8	do...	44 by 130 by 6	Crib No. 12	do...	26 by 280 b
Crib No. 9	do...	38 by 150 by 6	Crib No. 13	do...	26 by 74 b
Crib No. 10	do...	38 by 24 by 6	Crib No. 14	do...	20 by 400 b

As the work on this spur covered the whole of one and part of a second season would be somewhat confusing to separate the data following, so I have consolida it for the entire spur.

Cost and material.

3,216.34 cords brush, at $1.68	$5,403.
194.11 cords poles, first grade, at $3	582
14.64 cords poles, second grade, at $2.75	40
6,200 feet, B. M., 2 by 4 inch lumber, at $11	68.
74,016 feet, B. M., 3 by 6 inch lumber, at $10.90	74
2,138.75 tons rock, at $2	4,277
5,510 pounds galvanized wire, No. 10, at 4 cents	22
38 kegs steel wire nails	109.
16½ kegs wrought spikes	49.

3 kegs cut nails	$19.15
1,160.48 pounds iron rods, chains, etc., at 3½ cents	285.62
Three kedges, including rock	17.03
Pay-roll, services	11,395.26
Rations, approximated, 3,300, at 30 cents	990.00
Chartered tug	1,040.00
Tug *Tilda* ninety-nine days, at $20	1,980.00
Total	27,224.55

Square feet of mattress in spur	$68,500
Pounds of rock per square foot to sink	13.87
Cost per square foot in place	$0.07¼
Cubic feet of crib-work in spur	447,486
Pounds of rock per cubic foot to sink	7.436
Cost per cubic foot in place	0.04\frac{274}{1000}$
Total time occupied in construction of spur—days	123
Sundays and holidays—do	15
Rain and storm—do	12
High water and drift—do	22
Actual working time—do	74
Maximum length of spur—feet	430
Maximum height of spur—do	60
Maximum depth of water at low water—do	152

The project estimated the cost of the Greenville Bend spurs at $12,000 each, and as the cost of Spur No. 1 was so greatly in excess of this, some explanation should be made. In the first place the size of the spur and cubical contents are about twice those of any of the spurs built in the Gouldsboro Bend, on which the estimate of $12,000 was based. The temporary disabling of the *Tilda*, the chartering of another tug, and the delay of twenty-two days from high water and drift, during which time a large force had to be retained on the work, added about $3,000 to what the expenses would have been even under favorable circumstances. The great depth of water in which the mattresses and cribs were to be sunk rendered extreme caution necessary, and in work of this character, depending in a great measure for its success on one man, caution means delay.

Notwithstanding all this it will be noted that the cost of mattress-work was less than that determined in the Gouldsboro Bend, and the cost of crib-work was slightly in excess. A careful study of the data given will, I think, afford any additional explanation that may be necessary.

On August 9 work on Spur No. 2, Greenville Bend, was commenced and it was finished September 21. As was the case on Spur No. 1, the plant was not large enough to weave in one piece the foundation mattress required, so an extra or built mattress was necessary. The dimensions of this mattress were 110 by 150 by 1.5 feet thick. It was sunk at the outer end of the spur in 160 feet of water, and was held in place by three wire ropes running to wooden kedges filled with rock.

Cost and material when in place were:

85.37 cords brush, at $1.68	$143.42
1,229 feet, B. M., 2 by 4 inch lumber, at $10.90	46.10
2,196 feet, B. M., 3 by 6 inch lumber, at $10.90	23.94
77.34 tons rock, at $2	154.68
240 pounds galvanized wire No. 10, at 4 cents	9.60
5½ kegs 6-inch steel wire nails, at $2.35	12.92
1½ kegs 9-inch steel wire nails, at $3.33	5.00
700 pounds 2-inch wire rope, at 8½ cents	59.50
Three kedges, including rock	17.00
Pay-roll, services	532.82
Rations, approximated, 200, at 30 cents	60.00
Tug *Tilda* four days, at $20	80.00
Total	1,144.98

Number of square feet in mattress	16,500
Pounds of rock per square foot to sink	9.37
Cost per square foot in place	0.06\frac{94}{100}$

The usual woven mattress was commenced as soon as the built one had been. In place the cost and material were:

285.82 cords brush, at $1.68	$4
42 cords poles, first grade, at $3	
9 cords poles, second grade, at $2.75	
322.95 tons rock, at $2	
5,901 pounds iron rods, chains, etc., at 3½ cents	
2,069 pounds galvanized wire No. 10, at 4 cents	
3 kegs 9-inch steel wire nails, at $3.33	
1½ kegs 6-inch steel wire nails, at $2.35	
1 keg 3½-inch steel wire nails, at $3.15	
Pay-roll, services	1
Rations, approximated, 877, at 30 cents	
Tug *Tilda*, eight days, at $20	
Total	3

Number of square feet in mattress	
Pounds of rock per square foot to sink	
Cost per square foot in place	

Construction of cribs for Spur No. 2 was commenced August 13. The dim. of the cribs were:

Crib No. 1	feet	56 by 40 by 6	Crib No. 5	feet	32 by 2
Crib No. 2	do	50 by 80 by 6	Crib No. 6	do	26 by
Crib No. 3	do	44 by 130 by 6	Crib No. 7	do	26 by 1
Crib No. 4	do	38 by 170 by 6	Crib No. 8	do	20 by 4

Cost and material were:

1,180.92 cords brush, at $1.68	$1.
101.21 cords poles, first grade, at $3	
1.34 cords poles, second grade, at $2.75	
1,034.93 tons rock, at $2	2.
37,300 feet, B. M., 3 by 6 feet lumber, at $10.90	
1,752 pounds galvanized wire, No. 10, at 4 cents	
20 kegs 9-inch steel wire nails, at $3.33	
2 kegs 6-inch steel wire nails, at $2.35	
Pay-roll, services	4.
Rations, approximated, 2,741, at 30 cents	
Tug *Tilda*, twenty-eight days, at $20	
Total	10.

Number of cubic feet of crib-work in spur	
Pounds of rock per cubic foot to sink	
Cost per cubic foot in place	
The total cost of the spur was	$14.
Total time to complete	days
Sundays and holidays	do
Rain	day
Out of brush	days
Actual working time	do

As in the case of Spur No. 1, the cost exceeded the estimate based on the Greenborough spurs, although the cost per unit—*i. e.*, square foot of mattress and cubic of crib work—was considerably less. It is certain that spur-dikes, as with most structures, cost in proportion to their size.

The completion of these two spurs in the Greenville Bend finished all work in locality authorized at present.

THIRD DISTRICT FRONT.

On September 20, 1889, immediately on completion of the spurs in the Green Bend, preparations for work in the Third District Bend, in the lower portion of city, were commenced. These preparations consisted chiefly in loading up the ba with rock and the lumber and other material on hand; moving and mooring the p at the new locality. The total cost of this, which may be called installation, $795.61.

The work proposed in the third district front was to consist of four (Nos. 1, 2, 4) submerged sloping spur-dikes, extending on a slope of three horizontal to one v

al from low-water mark to deep water in the channel of the river. In addition to this, ach spur was to be prolonged from the low-water mark back to the main levee by an arthen spur or levee, protected by a covering or pavement of rock, this covering to xtend 20 feet above and 50 feet below, to form aprons, and practically prolong the oundation mattress to the main levee. The ultimate result to be a continuous spur ommencing above high-water mark instead of at low.

I went onto this work with an organized force of trained employés, was favored vith exceptionally fair weather and very low water. The results of this combination re pretty well evidenced in this report.

Construction of Spur No. 1 was commenced September 28. The style of mattress sed on this and succeeding spurs was what is known as the "built" mattress, to dis- inguish it from the former style designated as "woven."

The dimensions of the mattress were 111.6 by 362 by 1.5 feet thick, and the cost and material were:

51.60 cords brush, at $1.68	$590.69
3.91 cords poles, first grade, at $3	101.73
3.98 cords poles, second grade, at $2.75	38.44
2,876 feet, B. M., 2 by 4 inch lumber, at $10.90	140.35
334 tons rock, at $2	668.00
578 pounds galvanized wire, No. 10, at 4 cents	27.12
11 kegs 9-inch steel wire nails	35.65
14 kegs steel wire nails 6-inch	38.42
1 keg 3½ inch steel wire nails	3.10
1,253 pounds iron rods, bolts, etc., at 3½ cents	43.85
Pay-roll, services	1,009.38
Rations, approximated, 650, at 30 cents	195.00
Tug *Tilda*, seven and one-half days, at $20	150.00
Total	3,041.73
Number of square feet in mattress	40,400
Pounds of rock per square foot to sink	16.53
Cost per square foot in place	0.07\frac{53}{100}$

The dimensions of the cribs built and sunk on this spur were:

Crib No. 1	feet..	40 by 90 by 6	Crib No. 3	feet..	24 by 234 by 6
Crib No. 2	do...	32 by 159 by 6	Crib No. 4	do...	16 by 312 by 5

The cost and materials were:

00.93 cords brush, at $1.68	$841.56
2.16 cords poles, first grade, at $3	66.48
7,124 feet, B. M., 3 by 6 inch lumber, at $10.90	186.65
91.05 tons rock, at $2	782.10
60 pounds galvanized wire, No. 10, at 4 cents	26.40
61 pounds iron rods, at 3½ cents	5.63
8 kegs 9-inch steel wire nails	26.65
1 keg 6-inch steel wire nails	2.75
Pay-roll, services	1,381.59
Rations, approximated, 1,469, at 30 cents	440.70
Tug *Tilda*, thirteen days, at $20	260.00
Total	4,020.51
Number of cubic feet of crib-work	115,776
Pounds of rock per cubic foot to sink	$6\frac{786}{1000}$
Cost per cubic foot in place	0.03\frac{47}{100}$
Total cost of the subaqueous portion of the spur was	$7,062.24
Total time to complete	days.. 24
Sundays	do... 3
Actual working time	do... 21

On crib construction five days were lost on account of non-delivery of brush.

Construction of Spur No. 2 was commenced October 23. The style of mattress was the same as on Spur No. 1, and its dimensions were 102.75 by 344 by 1.5 feet thick. The cost and material were:

328.64 cords brush, at $1.68	$552.12
19.65 cords poles, first grade, at $3	58.95
11,500 feet, B. M., 2 by 4 inch lumber, at $10.90	125.35
1,000 feet, B. M., 3 by 6 inch lumber, at $10.90	10.90

197.5 tons rock, at $2	$
753 pounds galvanized wire, No. 10, at 4 cents	
12½ kegs 9-inch steel wire nails	
14 kegs 6-inch wire nails	
1 keg 3½ steel wire nails	
1,414 pounds iron rods, at 3½ cents	
56 pounds fish-plates, at 4 cents	
28 bolts ¾ by 27 inches, at 15 cents each	
Pay-roll, services	
Rations, approximated, 600, at 30 cents	
Tug *Tilda*, five days, at $20	
Total	2,

Number of square feet in mattress	
Pounds of rock per square foot to sink	
Cost per square foot in place	$0.

The dimensions of the cribs built and sunk on this spur were:

Crib No. 1	feet	32 by 11
Crib No. 2	do	24 by 2
Crib No. 3	do	16 by 3

The cost and material were:

361.54 cords brush, at $1.68	$
10.28 cords poles, first grade, at $3	
16.66 cords poles, second grade, at $2.75	
13,350 feet, B. M., 3 by 6 inch lumber, at $10.90	1
378.81 tons rock, at $2	
369 pounds galvanized wire, No. 10, at 4 cents	
7 kegs 9-inch steel-wire nails	
1½ kegs 6-inch steel-wire nails	
161 pounds iron rods at 3½ cents	
Pay-roll, services	
Rations (approximated) 600, at 30 cents	1
Tug *Tilda*, 7½ days, at $20	1
Total	2,

Number of cubic feet of crib-work	
Pounds of rock per cubic foot to sink	
Cost per cubic foot in place	$0.

The total cost of the subaqueous portion of the spur was $5,244.90.

Total time to complete	days
Sundays	do
Rain and storm	do
Actual working days	do

On crib construction one day was lost from non-delivery of brush.

Construction of Spur No. 3 was commenced November 19, although the last crib Spur No. 3 had not yet been sunk. The dimensions of the mattress were 102.7 344 feet by 1.5 feet thick, and the cost and material were:

271.01 cords brush, at $1.68	$45
30 cords poles, first grade, at $3	
12,000 feet, B. M., 2 by 4 inch lumber, at $10.90	1
1,000 feet, B. M., 3 by 6 inch lumber, at $10.90	1
228.20 tons rock, at $2	45
720 pounds galvanized wire, No. 10, at 4 cents	
13 kegs 9-inch steel-wire nails	4
19 kegs 6-inch steel-wire nails	5
161 pounds 3½-inch steel-wire nails	
1,549 pounds iron rods, bolts, etc., at 3½ cents	4
80 pounds fish-plates, at 4 cents	
38 bolts, ¾ by 27 inches, at 15 cents each	
Pay-roll, services	75
Rations (approximated) 680, at 30 cents	2
Tug *Tilda*, 5½ days, at $20	1
Total	2,40

ımber of square feet in mattress	35,054
unds of rock per square foot to sink	13.02
ıst per square foot in place	0.06\frac{847}{1000}$

The dimensions of the cribs built and sunk on the spur were:

·ib No. 1	feet.. 32 by 38 by 6	Crib No. 3	feet.. 24 by 238 by 6
·ib No. 2	do... 32 by 38 by 6	Crib No. 4	do... 16 by 260 by 6

The cost and material were:

5.81 cords brush, at $1.68	$513.76
.41 cords poles, first grade, at $3	76.23
.15 cords poles, second grade, at $2.75	58.16
19.40 feet, B. M., 3 by 6 inch lumber, at $10.90	130.15
5.64 tons rock, at $2	611.28
5 pounds galvanized wire, No. 10, at 4 cents	7.80
72 pounds galvanized wire, No. 8, at 4 cents	6.88
kegs 9-inch steel-wire nails	28.32
61 pounds iron rods, at 3½ cents	5.63
'ay-roll, services	1,020.09
ations (approximated) 450, at 30 cents	135.00
'ug *Tilda*, 6⅓ days, at $20	166.67
Total	2.759.84

Number of cubic feet of crib-work	84,824
Pounds of rock per cubic foot to sink	7.206
Cost per cubic foot in place	0.03\frac{743}{1000}$

The total cost of the subaqueous portion of the spur was $5,160.37.

Total time to complete	days.. 22
Sundays	do... 3
Rain and storm	do... 1
Actual working days	do... 18

Construction of spur No. 4 was commenced November 29. The dimensions of the foundation mattress were 118 by 322 feet by 1.5 feet thick, and the cost and material were:

286.36 cords brush, at $1.68	$481.08
33.85 cords poles, first grade, at $3	101.55
3,500 feet, B. M., 2 by 4 inch lumber, at $10.90	147.15
2,700 feet, B. M., 3 by 6 inch lumber, at $10.90	29.43
294.39 tons rock, at $2	588.78
55 pounds galvanized wire, No. 10, at 4 cents	30.20
7 kegs 9-inch steel-wire nails	56.65
8 kegs 6-inch steel-wire nails	49.40
5 pounds 3½-inch steel-wire nails	2.65
1,800 pounds iron rods, at 3½ cents	63.00
108 fish plates, at 7 cents each	7.56
108 bolts, ⅞ by 2½ inches, at 5 cents each	5.40
30 bolts, ¾ by 27 inches, at 15 cents each	4.50
Pay-roll, services	1,045.29
Rations (approximated) 660, at 30 cents	198.00
Tug *Tilda*, 5⅔ days, at $20	113.33
Total	2,923.97

Number of square feet in mattress	37,996
Pounds of rock used per square foot to sink	15.5
Cost per square foot in place	0.07\frac{695}{1000}$

Owing to the higher stage of the river and swifter current this matress was built considerably stronger than the others. This, together with delays from heavy drift, made it more expensive than the mattress on Spurs 2 and 3.

The dimensions of the cribs built and sunk on Spur 4 were:

Crib No. 1	feet.. 48 by 92 by 6	Crib No. 4	feet.. 24 by 260 by 6
Crib No. 2	do... 40 by 136 by 6	Crib No. 5	do... 16 by 276 by 6
Crib No. 3	do... 32 by 186.6 by 6		

The cost and material were:

621.96 cords brush, at $1.68	$1,04
79.97 cords poles, first grade, at $3	2
24,090 feet, B. M., 3 by 6 inch lumber, at $10.90	2
403.80 tons rock, at $2	8
823 pounds galvanized wire, No. 10, at 4 cents	
235 pounds galvanized wire, No. 8, at 4 cents	
16 kegs 9-inch steel-wire nails	
1 keg 6-inch steel-wire nails	
215 pounds iron rods, at 3½ cents	
Pay-roll, services	2,5
Rations (approximated), 990, at 30 cents	2
Tug *Tilda*, 13½ days, at $20	2
Total	4,5
Number of cubic feet of crib-work	161
Pounds of rock per cubic foot to sink	
Cost per cubic foot in place	$0.0

The total cost of the subaqueous portion of the spur was $7,444.90.

Total time to complete	days
Sundays and holidays	do
Rain and storm	do
Actual working days	do

During the construction of this spur there was a considerable rise in the r accompanied by heavy drift. This, together with dense fogs and the holiday sea delayed the work and increased the expense. The work required in the proje complete Spurs 1, 2, 3, and 4 on the third district front, that is the spur levees p longing the crib-work back to the main levee and above high-water mark, I am pelled to consolidate, as the force engaged was constantly shifted from one spu another, depending on the supply of material and the necessity of haste on the s aqueous portions of the spurs.

I give a general description of this work. On the center line of each spur an ear levee with crown of 10 feet and side slopes of 3 and 3 to 1 was staked off. levee extended from the main levee to the crib-work of the spur. The bank ab and below it, where necessary, was graded to a reasonable slope, all holes and equalities being filled up and leveled off. On the completion of the earthen lev was covered with a layer of broken rock or brick 9 inches thick, and extending form aprons 20 feet above and 50 feet below the spur levee. The project cont plated using gravel for this purpose, but the material mentioned was obtained a reasonable cost and was equally as good. The broken rock or trash was the bal of ships coming to the port, and the bricks were the refuse from brick-yards. this layer of broken rock or brick was laid by hand a rough pavement of large r about 9 inches thick. Over this to fill in the voids was scattered broken rock, whole forming a substantial covering 18 inches thick of material that will not wa away or decay.

The following is a consolidated statement of cost and material for all four spurs

1,839.39 tons rock, at $1.50	$2,75
694.94 tons broken rock, at 75 cents	52
508.55 cubic yards of broken brick	17
1,832 cubic yards of earth	
Pay-roll, services	2,77
Rations, approximate, 2,135, at 30 cents	64
Tug *Tilda* fifty days, at $20	1,0
Total	7,86
Contents of spur levees and aprons as computed ..... cubic yards	4
Cost per cubic yard, completed	1.8

I fear that the figures which I have given in this report are somewhat misleadi To avoid this I would state that on all the work the cost given is the bald cost computed and incurred under my immediate supervision in the field.

It does not include cost of large plant, such as barges, or care, preservation, and pair of same; nor of small plant, such as hawsers, lowering lines, tools, appliance and the thousand and one small purchases incident to a work of this character. does not include expenses in main office, such as traveling expenses, salaries, re stationery, etc., nor installation on work.

There are now twelve spur-dikes completed in the harbor. I do not know the total mount expended on this work to date, but if it were ascertained, the present value f the plant deducted, and the remainder divided by twelve, it would give the actual verage cost of each spur. Fluctuating appropriations, unfortunate delays, etc., while they may explain will not alter the fact that the work is and is likely to continue to be very expensive through causes over which your executive force have no control.

As an offset to this, it may be stated that there is now every reason to believe that the work has been successful. The spurs are standing and accomplishing the results for which they were built.

Without elaborate drawings, photographs, etc., it would not be possible to give a proper idea of the methods employed or the details of spur-dike construction. Suffice it to say that nothing is done in a hap-hazard or careless way, but is the result of careful study improved by experience. From the time a mattress or crib is placed between the double line of lowering barges until it rests in its proper position on the bottom it is fully under control. No one unless those who have seen it can realize the accuracy with which the different structures are placed in water 100 feet deep and more. The profiles of the completed spurs are sufficient evidence. Improvements in details have been constant. Amongst the most important may be mentioned the use of a "mooring barge" from which all the mooring and toggle lines, are managed, the use of steel wire ropes instead of manilla hawsers for mooring lines, the substitution of the "built" for the "woven" mattress.

During the season's work no incident worthy of mention occurred. From date of commencement until work was suspended on account of high water, operations were carried on smoothly and successfully. The season throughout was the most favorable that I have ever known and a similar one is not likely to occur for some years.

The only disaster occurred since the plant has been laid up. On the night of May 8 the tug *Tilda*, which had rendered such excellent service in the harbor, was almost destroyed by fire. She had been absent on levee work at the Nita Crevasse and a few hours after her return was discovered to be in flames.

SUMMARY.

The working season of 1889–'90 commenced June 22, 1889, and all work in the Greenville Bend and third district front under the approved project was completed January 20, 1890, at which time the river had risen to a stage that prevented further work.

Total length of working season, days	213	Volume of cribs built and placed in spurs.....cu. feet..	974,287
Sundays.....days..	30	Quantity of brush used ..cords..	6,050
Holidays.....do...	3	Quantity of poles used ....do...	550
Bad weather .....do...	9	Quantity of lumber used, feet, B. M	201,300
Non-delivery of brush.....do...	5	Quantity of rock used ....tons..	6,956
Actual working time.....do...	166		
Area of mattresses built and placed in spurs.....sq. feet..	209,254		

At date of this report the river is generally out of its banks. The plant is in laying up quarters and, thanks to your wise policy, is generally in good condition, a large portion as good as new. Barge No. 3, now six years old, is being rebuilt. The *Tilda* has been docked in a coal-barge and the work of repairing the damage done by the fire is being pushed as rapidly as possible.

Mr. William Garvin has been a faithful and efficient overseer, and, together with Mr. Jos. Ralley, time-keeper, has been of great assistance in accumulating the data given in this report.

In conclusion I would state that while every reasonable and proper economy has been exercised, such economy has never been at the expense of the character of the construction. It is, I believe, the best of its kind. I only hope that the third district work may not be taken as a criterion of cost. The results were obtained by an amount of hard work, persistent endeavor, experience, and watchfulness on the part of the principal employés which I would not be prepared to guaranty on all future work. The third district spurs were estimated in the consolidated project to cost $49,000. As computed in this report the cost was $33,574.48, a saving of $14,425.52.

Very respectfully, your obedient servant,

H. S. DOUGLAS,
Assistant Engineer.

Capt. DAN C. KINGMAN,
Corps of Engineers, U. S. A.

REPORT OF MR. W. G. PRICE, ASSISTANT ENGINEER.

SIMMESPORT, LA., *May* 31, 189.

CAPTAIN: I have the honor to submit the following report of work done for rectification of the Red and Atchafalaya rivers:

On the 31st of May, 1889, the condition of the work was as follows: Dam No. the Atchafalaya had been completed and work on Sill No. 3 had been suspended account of high water. The fourth and last dump-scow and second large quar boat were in course of construction, and a rock-quarry was in operation at Harris burgh, La. The work at the quarry was suspended June 12, owing to low water, L tons having been delivered at Turnbull's Island. The fourth dump-scow, sec quarter-boat, and two small barges for carrying coal and other supplies were co pleted in July. The three quarter-boats which had been borrowed from the work Plum Point were repaired and returned to that work August 7. Ways were construc on the bank of the river and five willow barges were hauled out and repaired a total cost of $2,274. The sides and rakes were sheathed with 2-inch pine and decks with 1¼-inch pine. A covering of felt and pine tar was put on under sheathing, but it was found necessary to calk the seams in the sides and rakes afterwards, so the felt was of little benefit except on the decks. This work was finish November 23.

OLD RIVER.

The dredge *Pah-Ute* (Menge patent) was moved to upper Old River June 15, a began dredging out shallow places and depositing material on one side of cut August 7, when the water was too high. Four thousand three hundred and nine two cubic yards were dredged at a cost of 16.5 cents per cubic yard. On August the dredge began work in lower Old River at Ash Cabin, but was soon moved to t bar at the mouth which was cut through September 11, and the work of cutt through second crossing to foot of Turnbull's Island was begun. On October 24 t dredge was returned to the mouth and again cut a channel through the bar assist by the launch *Ruby* washing with her wheel. On October 31 the dredge was move to Ash Cabin again and continued cutting out mud-lumps till November 22. Fr October 25 to November 8 only very small light-draught boats could pass throu Old River, but on the latter date navigation was resumed, the mud-lumps in vicin of Ash Cabin, which were the principal obstruction, having been removed by t dredge, and the steamers *John D. Scully* and *Dacotah* passed through. The gauge Barbre's on that date read 2.6 feet, and at Red River Landing the gauge read 3.1 fee Navigation was resumed at a much lower stage than for many years. There wa some sloughing of the banks in vicinity of Ash Cabin, but not as much as last yea The banks are apparently becoming stronger, so the sloughing will eventually cease The total amount of material dredged in lower Old River was 47,480 cubic yards, a a cost of 8.9 cents per yard, of which 1,761 cubic yards were removed in scows to Dam No. 3 in the Atchafalaya. The dredge was very imperfect at first and was continu ally breaking down, but the defects were remedied finally so that good work was done

SILL AND DAM NO. 3 IN THE ATCHAFALAYA.

On June 5 a force began cutting willows in Old River, and on July 3 mat construc tion was begun. The Sill No. 3 was completed August 27, and Dam No. 3 was com pleted September 15. The method of construction was the same as for Sill and Dam No. 1. The dredge loaded 1,570 cubic yards of clay on scows at mouth of Bayo Des Glaise and 1,761 cubic yards in Old River, which was dumped in the successive layers of crib-mats in dam. All the mats were ballasted with rock. No gravel was used owing to the difficulty in obtaining it. At first there was too much water over the gravel-bars in the Mississippi, and afterwards the services of the dredge were required in Old River.

Material used.—Willows, 5,608 cords, at $1.59, delivered; rock, 3,635 tons, at $2.30 delivered; clay, 3,331 cubic yards.

There were constructed, ballasted, and sunk 975,990 cubic feet of crib mats at a cost of 3.4 cents per cubic foot. The cost of constructing mats including material was 1.6 cents per cubic foot, all expenses included except cost of plant and unexpended material.

In April, during the highest water, there was a perceptible fall over this dam and the velocity was very great. The strongest stern-wheel boats could not pass up except by going close to shore. At the discharge section, located 850 feet below the center of the dam, the area of the section below zero of Simsport gauge increased 31 per cent. from March 6 to May 14. I think this indicates that it will be necessary to put in more dams to distribute the fall over a longer reach.

DAM FOR DEFLECTION OF RED TO UPPER OLD RIVER.

Work was begun on the sill September 9 and it was completed November 15. That portion of the sill which is below 10 feet on the Barbre's gauge was constructed of brush mats 3 feet thick, same as used in Atchafalaya sills. The sill is 280 feet wide in the deep water and tapers out to 200 feet wide where the ends of the dam are to be. Twelve mats were constructed, containing 755,400 cubic feet, at a cost of 1.43 cents per cubic foot. The cost of mats ballasted and sunk was 2.65 cents per cubic foot, all expenses included except cost of plant and unexpendable material. All the mats were strongly wired together at their edges, one after another, as they were being sunk, and the whole was put down in one continuous piece from one side of the river to the other. The mats were ballasted with 23 pounds of rock to the square foot. The direction of the sinking was across the river, the rock being thrown on the mats from barges which were pushed over the mats as they went down. Owing to the slack current the work of sinking was extremely easy and cheap and the perfect covering of the bottom was a certainty. The sill over the bar and up the bank on each side is 200 feet wide, and was made by laying down two courses of willows, 3 to 4 inches thick, crossing each other, the direction of the willows in each course being diagonal to the sill. This was ballasted with rock piled in rows 12 feet apart and running across the river. Twenty-four pounds of rock to the square foot was used on the bar and right bank and 28 pounds per square foot on left bank. The area covered was 407,720 square feet, and cost 5.7 cents per square foot. A portable railroad with cars hauled by mules was used to distribute the rock over this portion of the work. The track led over a trestle to the rock barges in the river. The rock was obtained at Harrisonburg and Pineville, La., and had been stored in the vicinity during the preceding high water. The willows were obtained from the bars in the immediate vicinity. Grading was only required on the left bank, which was cut to a slope of four to one, using a water jet from pile-driver pump. The new quarter-boats enabled us to take much better care of the force employed and there was much less sickness.

Material used.—Five thousand seven hundred and fifty-seven cords of willows, at $1.31, delivered; 7,815 tons of rock, at $2.30, delivered; 113,392 feet of lumber, at $15 per M, delivered.

On November 16 the plant was moved to Plaquemine to be used in constructing submerged spurs.

REPAIRS TO PLANT.

On February 6 the plant arrived at Simmsport from Plaquemine. A dock was constructed out of an old coal-boat, in which the launches *Ruby* and *Alaska*, quarter-boats *Alpha* and *Beta*, and tug *Comstock* have been docked and had their hulls thoroughly repaired, calked, and painted. A new cabin is being built on the *Comstock* and improvements and repairs are being made to her machinery. All the barges in the plant have been put in good order except three old ones which are not worth repairing. Owing to the very high water most of the property had to be moved from the buildings on shore and stored on the barges and quarter-boats.

SURVEYS.

Sections in Atchafalaya from Barbre's to Simmsport were resounded in November. Sections in Morganza were resounded in October.

DISCHARGE OBSERVATIONS.

I began measuring discharge at Red River Landing February 20, and at Simmsport March 6, using current meter. Since March 20 Mr. G. Ed. Mott has been the observer. Twenty-one discharges have been taken at Red River Landing, fourteen at Simmsport, and two at Natchez. All have been computed.

PROTECTION OF LEVEES.

The launches *Alaska* and *Ruby* have been employed most of the time since March 19 in the work of protection of levees between Simmsport and Bayou Sara, Louisiana. A large amount of lumber and sacks was distributed by the *Ruby*. The *Alaska* was used in patrolling the levees, and being a very fast boat material was taken to threatened points very quickly. A pile-driver was also kept ready for work with a supply of tongued and grooved sheet-piling aboard. The piling was made of three planks, each 2 inches by 12 inches, bolted together. The center planks were all carefully dressed to the same thickness, and they projected 2¼ inches beyond the edges of the other two to form the tongue and groove. The driver was used only once, where a bad hole through a large levee at Fisher's Landing was stopped by driving sheet-piling

on the river side. The levees nearly over the whole line had to be raised, and were successfully held against the rising river till April 21 and 22, when a severe and wind storm caused many breaks. Soon after the Morganza Levee broke a mattress was constructed and sunk to hold the lower end of the levee, which was caving away at the rate of 100 feet per day, and it has successfully protected the end of the levee. It was constructed, in accordance with your direction, of willow fascines 50 feet long and 1 foot in diameter, bound with rope. Enough fascines were fastened together side by side to make a mat 50 feet by 125 feet. It was built in ways placed on the slope of the levee, and when finished was towed to place and sunk. Nothing but willow brush and rope was used in constructing it, as it was ballasted with rock in double sacks tied on to the ropes in mat. One end of mat was supported by a small lowering barge, and the swift current running over the mat helped to support it while the rock was being tied on. The men began to rock on the end nearest the crevasse, and moved along gradually as the mat sunk down so their trips were in water. When all the rock was in place the end of the barge was quickly lowered to the bottom. The fascines made the mat stiff in one direction, and prevented its doubling up, and as they were fastened with rope the mat was very easy to bend in the other direction, and it wrapped around the end of the levee very nicely. When sunk the mat was 60 feet from end of levee, and the levee caved away till the mat wrapped around the end.

MISCELLANEOUS.

Cost of subsistence during the year.

Cost of raw ration, including ice ..... cents...
Cost of ration cooked and served, including ice ..... do...

Expense of steam-boats while in commission.

Tug *Comstock* ..... per day...
Launch *Ruby* ..... do...
Launch *Alaska* ..... do...

Very respectfully, your obedient servant,

W. G. PRICE,
Assistant Engineer

Capt. DAN C. KINGMAN,
Corps of Engineers, U. S. A.

REPORT OF MR. WILLIAM GARVIN.

NEW ORLEANS, *March* 24, 18[illegible]

SIR: I have the honor to submit the following report of the observations taken at Harlem Crevasse:

The break measured 49 feet in length with 8 feet depth on up-stream and 7 feet on down-stream end. The greatest velocity of the current, taking a distance of 100 feet, 50 feet on river and 50 feet on land side of center line of levee, I found to be 600 feet per minute or 6.81 miles an hour.

The floats used were pieces of timber 3 by 6 by 10 inches; the distance was obtained by mooring the skiff to a willow on river side of crevasse and running a lead line with buoy on lower end. The man in skiff would call time when start float and another call time when the float passed the buoy. I also ran floats from 100 feet outside to center line of levee; the velocity there I found to be 750 feet per minute or 8.52 miles an hour, which, in my opinion, is the most correct, as a very heavy drift lodged 75 or 80 feet below crevasse, caused a great many whirlpools and breakers below or on land side of center line of levee. At times the floats would stand stationary for a second or two on the breakers and under the most favorable circumstances would require six seconds to run the lower 50 feet. This drift also made it very dangerous to attempt to sound the center of break.

The gentlemen who were in charge of the work closing the break thought it much deeper in the center, but from the appearance of the flow of water I could see no reason why it should be much, if any, deeper than I found it, 5 feet from each end.

Assuming the depth to be 8 feet and velocity of current 750 feet per minute, the break would have a capacity of 294,000 cubic feet a minute.

On my way down I passed the Jesuits Bend break; it being behind quite a wide batture and heavy growth of willows, it could not be seen from the river. I returned to this break at 4 p. m., but owing to the location found it impossible to take

ccurate measurements; the willows at this point grow within 15 feet of the levee, hich made it impossible to run floats through the break. There were no obstructions n the land side of this break, and I ran some floats from center line of levee, es- imating the distance, and found that it required from seven to nine seconds for them o run 100 feet; the same results as at Harlem break on the river side. There was .5 feet of water on ends of break, but every appearance of a greater depth near cen- er; I estimate the length at 90 feet.

It would have required five or six hours' time to take accurate measurements and oundings in the Jesuit Bend crevasse.

Should I be sent out on work of this kind again, I will have a better knowledge of what is required and be prepared for any emergency.

Very respectfully your obedient servant,

WILLIAM GARVIN.

Capt. DAN C. KINGMAN,
Corps of Engineers, U. S. A.

REPORTS OF MR. B. J. OLIVEIRA, OBSERVER.

NEW ORLEANS, *March* 24, 1890.

CAPTAIN: I have the honor to submit the following report of the observations taken at "Nita Crevasse," St. James Parish, La., about 63 miles above New Orleans, March 23, 1890:

The break measures 642.1 feet in width, and an average depth of 14 feet. The velocity of current through the break was ascertained by surface floats, and was found to be 12.44 feet per second. To ascertain the mean velocity, 20 per cent. reduction was taken from same, leaving 9.925 feet per second, thus making the actual discharge 89,462.5 cubic feet per second. The floats used were made with pieces of timber 4 by 6 by 12 inches, the distance being ascertained by measuring between the old and new levees, and was found to be 140 feet. A man was stationed at the end of the old levee, and the float was thrown, and when it passed in line he would call, and another man was stationed at the end of the new levee who would call time when the float passed in line with him. Ten floats were used. The time was accurately registered for each float. The greatest time for a float to pass said distance was thirteen seconds, and the shortest time was nine and one-half seconds. The Mississippi Valley Railroad Company have built about 80 feet of piling out from the north end of the crevasse, and soundings were taken from the piling with results varying from 13 to 15 feet in depth. Platforms were also rigged with an upright post in the center varying from 12 to 20 feet. The posts were worked on a pivot, and railroad iron lashed to the bottom of each post. One at a time was sent through the crevasse. Every time they would touch bottom the projection at the top would be pushed to an angle, and by experimenting in this way I ascertained the average depth of the break to be 14 feet.

Very respectfully,

B. J. OLIVEIRA,
Observer.

MARCH 25, 1890.

Since the date of my report, I have learned from the officials of the Mississippi Valley Railroad Company that a cave of 20 feet more has occurred at the south end of the crevasse.

B. J. OLIVEIRA.

Capt. DAN. C. KINGMAN,
Corps of Engineers, U. S. A.

NEW ORLEANS, MAY 21, 1890.

SIR: I have the honor to submit the following report of discharge measurement taken at Nita Crevasse May 20, 1890:

The accompanying sketch [sketch omitted] will show the line followed to obtain observation, which I judged to be a section of the water passing through the break. The line starts at a point 3,500 feet back of the levee, at north end of break, and continues until within 450 feet of the south end, where the current was too strong to proceed further.

Twenty-two soundings were taken with a pole, the depths ranging from 5 to 12 feet, and the same number of meter readings, taken with a "Price" current meter No. 23, with results showing velocity of 4.25 to 8.437 feet per second, making the total discharge for actual line taken to be 301,985 cubic feet per second.

I think about 45,000 cubic feet should be added to the discharge as allowance the 450 feet at south end of crevasse where the current is very strong, and a 10,000 cubic feet for water wasted at north end in space between the levee, and feet where section begins, which would make total discharge of crevasse 3 cubic feet per second.

Very respectfully, your obedient servant,

B. J. OLIVEIRA.

Capt. DAN C. KINGMAN,
Corps of Engineers, U. S. A.

NEW ORLEANS, *March* 26, 1

CAPTAIN: I have the honor to submit the following report of the observa taken at "Live Oak Crevasse," Plaquemine Parish, La., about 26 miles below Orleans, right bank.

The same method was used in obtaining the necessary information as for the Crevasse," with the following results:

The break measures 116.7 feet. Average depth, 6½ feet; average velocity, 7.75 per second. Discharge, 5,881.8 cubic feet per second. There is a heavy growth of lows in front of the break, which causes the small rate of velocity.

Very respectfully, your obedient servant,

B. J. OLIVEIRA,
Observe

Capt. DAN C. KINGMAN,
Corps of Engineers, U. S. A.

REPORT OF MR. W. J. HARDEE, ASSISTANT ENGINEER.

NEW ORLEANS, LA., *May* 9, 18

CAPTAIN: In accordance with your verbal instructions of the 6th of May, spected and measured the Myrtle Grove and Nita crevasses and have the hon submit the following report of my observations:

Both crevasses were visited on the United States tug *Tilda*, the steamer ass in the work incidental to my observations.

Myrtle Grove plantation is situated 35 miles below New Orleans on the west of the Mississippi River. About one-half mile north of the residence of Mr. Wi son, the owner, is where the crevasse occurred. Here I found two breaks. By ferring with Mr. Wilkinson the history of the crevasses was learned.

During the morning of the 21st day of April a fearful wind storm prevailed. water was two-tenths higher than the grade of the levee and held by a line of ing. The line of levee in which these breaks occurred is a most miserable apo for a levee, and it is marvelous how it ever held water at all. During the perio flood and prior to the maximum height the levee had been re-enforced with placed on the back slope, giving it slight additional strength. The lower br occurred first. A large leak showed itself about 15 feet in the rear of the le spouting water from a 2½-foot diameter hole to a height of 3 feet. Mr. Wilki was on the levee at the time with his plantation force engaged in general protec work. A double line of hand-piling was immediately driven about the hole, ho shoe shaped, and when this had been filled with sacks and earth to a height of 4 the levee in front of the spout collapsed, creating the crevasse. This was at 11 m. of April 21, 1890.

At 1 o'clock of the same day the upper break, 260 feet above, occurred. The h wind prevailing at the time lashed the water into long running waves which sw over the levee with such force as to wash it badly. Here five small breaks occur directly due to wave wash; the small breaks gradually merged into one large o ing. The ends of both gave way rapidly for about four days when all enlarge practically ceased and the ends at present are not apparently washing at all. At time of my observation the water was just 1.8 feet lower than when the creva occurred. The original levee is about 5.5 feet high. Measures to close the creva were contemplated, but no work done. Here are the measurements found on M 1890. Break No. 1: Width, 295 feet; average velocity 5.04 feet per second; av age depth 3.5 feet; making a discharge of 5,153 cubic feet per second. Break No. Width 540 feet; average velocity 2.18 feet per second; average depth 5.5 feet; c charge 6,474 cubic feet per second.

The observations at Myrtle Grove completed, journey was continued to Nita C vasse, about 65 miles above New Orleans in St. James Parish, and measurements m May 8, 1890.

The origin of this break together with its early history is so well known that it will ot be repeated. No enlargement is taking place at the north end. The south end enlarging about 5 feet per twenty-four hours I was told.

By triangulation from opposite bank the width of the break was determined to be ,892 feet. The mean velocity deduced from eight measurements, taken at different oints in the crevasse, was 9.28 feet per second. The depth was found to range from 3 feet to as much as 20 feet immediately in the throat of the crevasse. The mean epth is placed at 15 feet. These measurements show a discharge of 402,566 cubic eet per second.

The following will serve to show the method by which measurements were ascer-ained at the crevasses herein reported on. The widths were determined by triangu-ation or stadia reading as was most expedient. Surface velocity was measured with loats between range lines, about equi-distant from and on either side of the center ine of levee. This surface velocity was reduced 20 per cent. to acquire mean veloc-ty. The currents in the crevasses were too strong to permit the use of boat and lead-ine; therefore the depths were measured with perpendicular pieces or poles placed on a pivot in a square frame made of wood so as to float. Above and projecting from the water about 4 feet of pole extended. The pole was weighted so that it could carry itself vertically when the float was launched and the pole met no obstacle. When the pole would come in contact with the bottom it would incline the upper extension. The angle was noted and the depth approximated. These lower poles were of differ-ent lengths and numerous floats were sent through the crevasses at different points until the depths were determined. Owing to the impossibility of securing an accurate profile or cross-section of the bottom, it must be remembered that the discharge fur-nished is only approximate. The measurements were taken in such manner, however, as to insure reasonably correct figures.

Very respectfully, your obedient servant,

W. J. HARDEE,
Assistant Engineer.

Capt. DAN C. KINGMAN,
Corps of Engineers, U. S. A.

REPORT OF MR. H. S. DOUGLAS, ASSISTANT ENGINEER.

NEW ORLEANS, *May* 19, 1890.

SIR: I have the honor to submit the following report, in compliance with your directions to give a history of the crevasses on Tensas Front, fourth district, with measurements of discharge, width and depth:

LAKE CONCORDIA.

I can not give any very reliable information as to the cause of the break, as my information is mostly hearsay.

Within 150 feet of the break I had had some work done at the junction of the run-a-round of the 1884 crevasse and the old levee. On April 18 I made a careful inspection of the levee in this vicinity, and walked over the particular place where the break occurred. No weakness was shown. If anything there was less seepage than elsewhere. An inspection of the map will show that in this locality there are a number of bayous large and small closed by the levee. The bayous are separated by high ridges.

On April 22, about 10 a. m., the levee gave way about 150 feet above the run-a-round of 1884 on a ridge where the levee was about 6 feet high. The water lacked about 1 foot of being to the top. Twenty minutes before the break occurred horsemen had ridden over the levee and detected no signs of weakness. As described to me, the water burst through the embankment about half-way between the crown and toe. The crown fell in and the Lake Concordia crevasse of 1890 was inaugurated. In a very short time it had enlarged to 50 feet, caving into one of the bayous. There never was the slightest hope of closing it, the bayou and the nature of the soil making such a task hopeless.

On the morning of the 23d I visited the crevasse and inspected the levee generally. The weather was perfectly horrible, and every available man was engaged in trying to prevent additional breaks, leaving the one that had occurred alone, which was very wise. The crevasse at this time was 200 feet wide, with a very swift current rushing through it and tearing its channel all to pieces. As the crevasse of 1884 cut a channel of 60 feet deep on the line of the levee I knew that this one would do about the same thing, and that there would be no hope of rebuilding the levee on the original line. The great danger was that the upper wing of the levee closing the crevasse of 1884 would be undermined from the rear. I directed that operations be confined

to preventing this instead of protecting the ends, as I was particularly anx have the lower end cave off, so that the direction of the current might be ch and deflected away from the rear of the wing previously mentioned. I gav tions to make small rough mattresses of willows fastened with rope and lo with sand-bags to prevent the wash at the base of the levee. I considered the have not changed my opinion, that protecting the ends was of minor importa that a certain amount of caving would be beneficial.

On April 27 I again visited the crevasse, and found that the gap had increa about 450 feet and that the current had slackened. A pile-driver and crew ha brought down from Vicksburg and a tug and barges had been chartered. A dike had been constructed at the north end of the break and was appare temporary benefit, although it appeared to me to be undercutting.

I next visited the crevasse on May 2. The pile-work at the north end st and but little caving had taken place. The lower end had caved into the wing of the levee of 1884, and as I hoped and believed all caving on the rea been almost checked. Another pile-dike had been built at the south end, but undercutting faster than the force engaged could pile in sacks and brush. My visit to the crevasse was on May 4. I found that the pile-dike at the south the crevasse had been undermined and flanked. The distance from the bu closing the deep channel of the crevasse of 1884 to the edge of the break was 35 and the end was slowly crumbling away into the deep channel that had been the rear of the levee. Nothing but a very strongly built mattress ballasted with would have been successful in holding the end. Owing to the peculiar shape crevasse and the local topography the cross-currents and eddies were as strong have ever seen. At the end of the levee the current was boring a hole very ne would have been done by a large auger.

In my judgment in the time that would necessarily be consumed in accumu the plant and material and constructing the mattress one of two things would hen: The river would fall and confine the crevasse water to the deep channel it had cut, or the break would have extended into the crevasse of 1884, when fu enlargement would not be likely to occur.

The following special features may be mentioned in connection with the Lak cordia Levee and Crevasse:

The soil on which the levee rests and of which it is built is peculiar. During the water it becomes a saturated mass, only held together by the sod. A pole can be p through it at almost any point. The land slope becomes too soft for a man to over, and the amount of seepage through the embankment is astonishing. The at which the present crevasse occurred is within a short distance of the Bayou Co dia, into which the water flowed and was conducted into a low uninhabited sw. Within five days after the crevasse took place the backwater generally, and, in ible as it may seem, immediately back of the break, commenced to decline. Be plantation, the one on which the crevasse occurred, was extensively overflowed within 1,500 feet on either side of the break the front lands were not injured plantations 5 miles above the break planting operations were scarcely inter with. The river has not yet caved its way into Lake Concordia except at the end, which is choked with a growth of willows, accumulated drift, deposit, etc. steam-boat route into the lake is through the old Waterloo Crevasse shown on th of Natchez and Vidalia Harbors. The line of old public and recent private leve the river front is nearly continuous to this channel. The result is that as the falls the crevasse is transferred from the lake bank to the river front.

On May 10 I measured the crevasse, with the following results:

Width	feet.
Maximum depth	do.
Average depth	do.
Maximum velocity in feet per second	do.
Average velocity in feet per second	do.

Discharge 47,042.33 cubic feet per second.

ARNAULDIA.

The location of this break is about 1 mile below the town of Vidalia. The ori break occurred on April 23, in a levee about 2 feet high, on a high ridge in fron plantation quarters. A short distance below this was a levée about 5 feet h recently built of almost pure sand and not sodded. Under the combined effects of and wave-wash this levee melted away. It is quite possible that both of these br could have been prevented by a little activity and energy, and but I fear that was lacking on the part of those immediately concerned. The Concordia Crevass occasioned something of a panic, and the people were engaged in getting their out of the country, anticipating a general overflow. The first break was of no im

ance, as it did not interrupt traffic on the public road immediately behind it, and the falling river quickly shut off the supply of water. On May 11 its channel was dry.

On May 11 I measured the existing crevasse, with the following results:

Width	feet	455.00
Maximum depth	do	3.50
Average depth	do	2.42
Maximum velocity in feet per second	do	2.00
Average velocity in feet per second	do	1.70

Discharge, 1,871.87 cubic feet per second.

HENDERSON-ASHLEY.

The only weakness of the Henderson-Ashley Levee was lack of height. It has a crown width of from 12 to 20 feet, and is, I believe, generally used as the public road. The weakest portion was a run-around built to close a gap caused by the caving into the river of a salient angle of the original line, and it was in this run-around that the break occurred. The levee, for a distance of about 4 miles, was generally overtopped by the flood, but it had been temporarily raised with lumber and sacks backed up with earth, making a second levee on the crown of the original one.

During the severe and prolonged storm of April 21, 22, and 23 breaks in this little levee on top repeatedly occurred, but they were closed. On the 23d, owing to the panic occasioned by the Concordia Crevasse, the force was somewhat demoralized and discouraged, and they let one of these little breaks get too far ahead of them. At this time the difference between the water in the river and the backwater behind the levee was about 4 feet. The crown of the old levee was too hard and compact to be cut away at once, but the rear slope, already softened by the backwater, washed away rapidly, until by undercutting of the crown the crevasse was made. It enlarged very rapidly to a width of 400 feet. On May 3 it had attained a width of 700 feet. The location of the crevasse is at the lower end of the Ashley plantation.

On May 12 I measured this crevasse, with the following results:

Width	feet	873.00
Maximum depth	do	13.00
Average depth	do	7.77
Maximum velocity per second	do	5.55
Average velocity per second	do	5.00

Discharge, 33,916.05 cubic feet per second.

METHODS.

The width of the breaks was measured with stadia. Depths were obtained with an ordinary lead line, and the soundings were taken from a skiff which was rowed across the jaws of the crevasse. Sixty-four good soundings were obtained at Lake Concordia, forty-seven at Arnauldia, and fifty-four at Henderson-Ashley. The measurements of velocity were made with an apparatus based on the old-fashioned log-line. It consisted principally of a reel on which was wound a light line or cord, tagged every 25 feet. To this was attached by bridle lines, so as to hold it square with the current, a triangular-shaped piece of thin board measuring 9 inches on a side. This was carefully weighted until its buoyancy was just overcome. A small float was attached allowing the board to sink 5 feet below the surface. One of the bridle lines was so arranged as to pull out when the board was suddenly checked by the log-line, and it could then be easily hauled in.

In operation two or more stations were selected about 75 feet outside the jaws of the crevasse. In most cases standing trees were convenient. The skiff was rowed up to and fastened to the station. The triangular board and the float were dropped overboard and the former immediately sank 5 feet below the surface. The current striking against the flat surface of the board pulled the log-line off the reel, which was arranged to run very freely. The stern of the skiff was taken as the zero point, and the time of the passage of the first tag was noted. The tags were then counted as they passed off the reel and the time noted on the passage of the fourth tag, thus giving a run of 100 feet. The board was then hauled in, the line wound up on the reel, and the whole operation repeated as many times as was considered necessary to obtain average velocity. The skiff was then removed to the next station, where the same observations were taken.

At Arnauldia, the depth being slight, and it being possible to measure a base at right angles to the break, the ordinary method of surface floats between two ranged lines was followed.

Very respectfully, your obedient servant,

H. S. DOUGLAS,
Assistant Engineer.

Capt. DAN. C. KINGMAN,
Corps of Engineers, U. S. A.

REPORT OF MR. W. J. HARDEE, ASSISTANT ENGINEER.

NEW ORLEANS, *May 2*[illegible]

CAPTAIN: I have the honor to submit the following report on crevasse m[illegible]ments in the parish of Pointe Coupée, and East and West Baton Rouge, exec[illegible] accordance with your verbal instructions of May 19, 1890:

Departed from New Orleans on the steamer *Jesse K. Bell* at 5 p. m., May [illegible] reached Bayou Sara at 5 a. m., May 21. Then proceeded by steamer *Stella* [illegible] Red River Landing, reaching there at 12.30 p. m. of the same day; secured a [illegible] made the passage to Simmsport, arriving at the United States fleet at 4.3[illegible] Found the steamer *Ruby* somewhat dismantled and about to be put in doc[illegible] boilers were washed, cylinders packed, the boat provisioned and fully equip[illegible] the trip, and left exactly at 8 p. m. Red River Landing was reached at 10.1[illegible] and the boat laid up for the night. Got under way at daylight May 22. At [illegible] met the steamer *Laura Lee*, and as our coal was light, and fearing we would n[illegible] a sufficient quantity to carry us to Bayou Sara, I borrowed twenty boxes fr[illegible] captain of the *Laura Lee* with the understanding it is to be returned to his [illegible] New Orleans. Early during the morning the

RACCOURCI CREVASSE

was reached. This crevasse is situated in the line of levee that crosses Br[illegible] Point. The line of levee extends from Raccourci Landing across the point t[illegible] courci Bend of Old River, thence on to Smithland where it resumes its positio[illegible] the bank of the Mississippi River. It was where this line of levee crosses the [illegible] tion of Mr. Horace Le Doux that the break occurred. The levee is a very o[illegible] When built in 1866 was very small, and has several times been enlarged. Mr. [illegible] Cotton, a planter living near by, who controlled a force of labor on the leve[illegible] the flood, reports that during the life of the levee while encountering high w[illegible] bad leaks showed themselves. These leaks were worked on and the mate[illegible] placed as to construct a camel hump both on the crown and side slopes. Many [illegible]lar points at present exist. The last time the levee was raised, some four yea[illegible] the contractor in putting the enlargement on the front side cut away some [illegible] humps on the back slope. It was where there had been a hump and which ha[illegible] cut away that the break occurred. There had been no unfavorable weakne[illegible] cated, and Mr. Cotton passed over the place only a half hour before.

At 9 p. m. of April 22 a spout of water as large as a flour barrel burst out [illegible] ground just where the back slope of levee meets same. In less than ten minute[illegible] crown of the levee collapsed, and for ten days afterwards the break rapid[illegible] creased until the present dimensions were reached, when all virtual enlarge[illegible] ceased. Height of levee in which break occurred is 6 feet.

The water at its highest, and at the time of crevasse, was flush with the g[illegible] and wave overflow detained by a line of planking. The present elevation o[illegible] water is 4.4 feet below the grade of levee. In the center of the crevasse a deep [illegible] has scoured, measuring as much as 40 feet, and as no such body is passing th[illegible] the break, the depths for discharge computations were taken on the batture in [illegible] and the velocity of current measured at the same point.

Statement.

Average of eight velocity measurements, per second.....
Average depth of ten measurements .....
Width of break ..... 5[illegible]

Discharge, 5,417.28 cubic feet per second.

Journey was continued, and shortly the

UPPER MORGANZA CREVASSE

was arrived at. This break is situated nearly a quarter of a mile from the [illegible] bank, in a very dense growth of young cotton-wood trees. The levee appears [illegible] a very stable piece of work, standing about 8 feet high and covered with a h[illegible] growth of closely cropped Bermuda grass. As the flood increased this levee was [illegible] to be too low, and was raised with sacks and earth until its elevation was incre[illegible] 1.1 feet. About midnight of April 21 the crevasse occurred, and was brought [illegible] by the waves lashing over the levee, which already fully saturated and soft p[illegible] an easy victim, and an opening was soon washed. At that time the water was al[illegible] flush with the new grade. On May 22, the date of my observation, the wate[illegible] just 7.7 feet below new grade. The crevasse waters were so turbulent as to m[illegible]

passage through the crevasse extremely hazardous, except at one point, where a successful journey was made. From the appearance of the water I judge large holes have scoured where the base of the levee rested. The depths were taken on a parallel line to levee, about 125 feet to river side. Here passage was made, in the skiff, through the trees, and was not only very difficult but very dangerous. Only expert boatmanship by the four in the skiff prevented capsizing. The current was measured on the line of soundings. The width was determined by stadia reading. The south end of the break is just 300 feet north of the 0 station of the new Morganza Levee. From an old negro fisherman, who frequents the crevasse daily, it was learned that all appreciable enlargement ceased several weeks ago, and the ends are now holding.

Statement.

	Feet.
Average velocity of seven measurements, per second	5
Average depth of eleven measurements	8
Width of crevasse	790

Discharge, 31,600 cubic feet per second.

All measurements completed we returned to the *Ruby* and dropped down to New Morganza; went in and followed the extreme southern chute, and in a few moments drew up at the south end of

NEW MORGANZA CREVASSE.

This break occurred about midway the new levee constructed in 1886–'87 by the State and Government jointly, and practically in the bed of the old crevasse. The levee was to all appearances very stable, and could have well stood a height of water within a foot of its top. It was well grown over with Bermuda grass. Owing to the great height pursued by the flood, it like many others had to be raised. The height was increased just 1.4 feet with sacks filled with earth and protected against wave overflow by line of planking. The crevasse occurred during the night of April 22. Its direct cause is not known, as no one was present. The space in front of crevasse is open and the wind has free action on the water. It is presumed that the water, when nearly flush with the new grade, agitated into waves, washed over, and created the break. For a short distance from each end there is a good stiff current, but out in the middle the current is very flat. The trip was made across the crevasse in a skiff and fifty-four soundings taken. The greatest water found was 19 feet, the least 1½ feet. By reference to the profile I find that the height of levee at north end of break was 13.2 feet. The water-surface at date of measurement, 5.7 feet below grade. This, then, if only the levee had washed away, should show a depth of 7.5 feet of water, but instead there were 13 feet showing a wash of 5.5 feet. At the south end, levee 9.5 feet high less 5.7 feet, should be 3.8 feet, but there were found 16 and 18 feet, showing a scouring of from 12 to 14 feet. Through the center of crevasse, where the ground was lowest, there was least wash, and where highest the most wash. The amount of wash or change of elevation ranges from 2 to 10 feet. As nearly as can be judged, the present profile would, in contour, closely compare with the original, but with a rather uniform difference in elevation.

The levee between the limits of break when constructed ranged from 5 to 24 feet in height. Owing to the difference in depth and velocities the discharge was calculated in divisions. On the 1st day of May Mr. Price, under your directions, successfully launched a large willow mat 50 by 125 feet, one end of which was connected with the south end of levee, the other allowed its freedom in the water, swung round, and now stands away from center line of levee at an angle of about 60 degrees. The end of mat is perfectly secure, and no enlargement has taken place since the mattress began serving its purpose of diverting the current from the end of levee. All enlargement at upper end stopped several weeks ago.

Statement.

	Feet.
Mean depth of fifty-six measurements	13.117
Mean velocity of fourteen measurements, per second	4.378
Width	2,543

Discharge, 146,034.88 cubic feet per second.

Measurements concluded, the return journey was through the same chute. The Mississippi River reached, the boat was headed down-stream, and after a short run the

SNEAD BREAK

was reached. Here the levee is of most inferior proportions. While well sodded, its crown is very small and the slopes insufficient. The levee stands 6 feet high. It

was originally much smaller, and increased to that height under a State ... about eighteen months ago. Mr. Snead reports that during the night of Ap... very heavy wind and rain storm prevailed. The water in the river was jus... flush with the top of the levee. At this point no sacking had been placed ... levee to raise it. A line of planking laid along the front edge of crown d... wave overflow. Immediately after the break, which occurred at 9 p. m., A... five large logs were found close by in the rear of the crevasse. No one havi... the crevasse occur, and not knowing its direct origin, it is thought by the re... that these immense logs were precipitated against the frail dike with such v... by the wind and waves as to burst through it. In this crevasse from the cent... of levee towards the rear a large scour is indicated on the water-surface. Ow... the turbulence of the discharging waters no soundings could be secured in t... mised hole. The depths registered were taken on a parallel line just in front ... river-side slope, and as current measurements were taken over same course a ... discharge was ascertained. All enlargement of break stopped within ten day... date of break. River now 5 feet below top of levee.

Statement.

Average depth of seven measurements .....
Average velocity of three measurements, per second.....
Width of break .....
Discharge, 3,139.92 cubic feet per second.

In the same line of levee and about 500 feet south of the Snead Break is the

STONEWALL OR LANAUX CREVASSE.

This break occurred about 9 p. m. of April 21. The water was flush with th... of the levee. To provide against wave-wash a line of planking was placed alon... river edge of crown. During the day of April 21 a most severe wind and rain s... prevailed, extending into the night. The waves lashed by the wind ran very ... and the planking proved inadequate to entirely oppose so severe a strain an... continued washing over of the waves tore an opening in the levee. This levee ... feet high. Its height was not increased during the flood. The piece where ... occurred had been thrown out and a run-a-round built in the rear of it. The ... round, however, was never used, as the levee thrown out was shortly afterward... larged and made a part of the system. To drain that little territory encompassed b... levees, about one-fourth of an acre, the new levee was cut. When break occurre... front line the discharging waters continued on through the opening in new levee ... by their force enlarged the ends of both openings. All enlargement took place ... ing first ten days succeeding date of crevasse. Water in river 5.05 feet below g... in levee.

Statement.

Average depth of seven measurements.....
Average velocity of three measurements, per second.....
Width.....
Discharge, 3,044.16 cubic feet per second.

Journey was continued, and a short run brought the boat to the

FANNY RICHE CREVASSE.

Here I found Mr. J. H. Stonaker, who informed me that this break occurred at ... a. m., of April 21. Shortly before that hour the tow-boat *W. W. O'Neill* passed ... mid-stream. The waves created by her wheel broke away a large amount of ... planking along this front. The planking gone, the swell occasioned a slight ... overflow at several points. At one of these points the crevasse occurred. Mr. S... aker passed by the place not longer than twenty minutes before. While return... and on reaching the spot referred to, he observed a large crack in the rear slop... the levee. This crack rapidly enlarged. A messenger was dispatched for a ... force engaged about a half a mile above. In less than ten minutes, and before ... force could arrive, the broken piece slid out, the crown collapsed, and the w... burst through. The break occurred within 150 feet of the present north end of ... vasse. Enlargement was rapid for first ten days, extending almost altogether do... stream. For past ten days no practical enlargement. This is a 6-foot levee. ... ing the period of the flood, for lack of height, this levee was raised 1.6 feet with ... and sacks, and the water stood about flush with the new top. On day of meas... ments river water 4.7 feet below new grade. Owing to great change of depth ... velocity at different points in the crevasse, the discharge is computed in divisio...

Statement.

	Feet.
Average depth of seventeen measurements	7.371
Average velocity of eight measurements, per second	4.354
Width	845

Discharge, 27,118.84 cubic feet per second.

It was now nearly sunset, and as Bayou Sara was reached night was fast approaching. A mooring was secured, and at daylight the following morning, May 23, we steamed away and headed for the point just below and on opposite bank, where is situated the

PRESTON CREVASSE.

Here I found Mr. W. H. Lewis, the manager of the Preston plantation, who kindly furnished me with the following history of the break and its closure. The crevasse occurred at midnight, April 21. During the flood the levee was seen to be too low to oppose the increasing water elevation, and was raised with sacks and dirt a total of 0.9 foot. To provide against wave-wash a line of planking was positioned at river edge of crown. No particular weakness was known at the point where crevasse occurred. No one was on the spot at the time. The general impression and conclusion is that the waves, then running very high from the storm winds, washed over, and so continued until the levee succumbed to the destroying agency. At time of break water was about flush with the increased grade. This crevasse was closed May 17 with a line of 4 by 4 foot piling driven perpendicularly about 4 inches apart and sufficiently braced with other small piling, connected by lateral bracing, to retain structure in its position. Sacks filled with earth were then deposited on the river side of the line of piling until an elevation above the water was reached and the body compact enough to check all free percolation. All material used was furnished by the United States Government. Work was commenced on May 12 under the general superintendency of Mr. Bennett Barrow, and, as stated, concluded May 17.

A large and deep hole has scoured in the body of the crevasse, measuring as much as 45 feet in places. Soundings were also made about half-way between center line of levee and crib work. As water receded in rear with closure of crevasse the material in levee between the ends of crib and ends of break were borrowed to fill sacks. The linear distance of levee cut away for such purposes amounts to 230 feet. On the north end the cribbing was started 132 feet from end of break. The greatest distance between cribbing and center levee line is at a point about one-sixth its distance from south end, where it measures 100 feet. Soundings were taken along the crib-work on the inside.

Statement.

	Feet.
Original height of levee	3.6
Raised height of levee	0.9
Width of break	213

Present river water, 3.5 feet below new grade. Water in break, 2.6 feet below river water.

About 3,000 feet below are two small breaks known as the

TAYLOR BREAKS.

Break No. 1 is the lower. This levee had been raised prior to the crevasse and protected from wave-wash by line of planking. About 9.30 a. m., April 20, the waves ran over the top of the levee creating the break. No scouring took place, and on May 11, this break was closed by a line of inch boards driven in the ground as piling, and re-enforced with sacks filled with earth deposited on the front side. This structure was placed immediately at foot of river-side slope. At the time of break water was just flush with new grade.

Statement.

	Feet.
Original height of levee	3.7
Raised height of levee	1.4
Present water under new grade	3.6
Average depth of break below new grade	3.4
Width of break	203

No. 2, or upper, situated about 600 feet north of No. 1, and is in the same line of levee. It was closed as No. 1, and on the same day, May 11.

Statement.

Original height of levee	
Raised height of levee	
Present water below new grade	
Average depth from new grade	
Width	

All of the foregoing crevasses are located in Pointe Coupee Parish, La., on the bank of the Mississippi River, the succeeding two in West Baton Rouge Parish, on west bank of the Mississippi River.

Measurements concluded at Taylor Breaks, the boat was headed for

POINT MANOIR,

where the conditions were peculiar. In the year 1886-'87 the State built what known as the Point Manoir Levee, extending from Hermitage Landing down-stream a little more than a mile. This levee was to succeed a then existing levee very near to the bank of the river—a levee expected to cave in at any time. The levee, however, stood until recently. When the flood of this year came the residents' line of action was on the front or old levee. The basin between the old and new levees measured a little more than a mile long and in the center was about 2,000 feet wide, the ends inclining towards the river to almost a point. This basin had been partially filled with water by means of siphon. Great care is usually expended in such instances to make an opening in an old levee on the completion of a new or back levee that the new work may feel the effects of the water slowly and not be exposed to a sudden strain. Here then was a new line of levee but three and a half years without having been thoroughly moistened, lying exposed and subject to the great expansion of heat, causing large cracks and otherwise promoting instability. As long expected, yet during the flood feared, a large cave occurred in the river back of Hermitage Landing, carrying in with it a large piece of the old levee. This caved at midnight April 30. The sudden rush of waters caused the opening to enlarge, it is now about 600 feet wide. So large a volume of water suddenly precipitated into the limited basin filled it rapidly, and within one hour after the cave the water in basin and river were of equal height, in places water standing flush with the top of the new levee. To all appearances the levee is a stable embankment. It has a full crown with regular and well filled slopes, all of which are closely covered with a heavy mantle of Bermuda grass.

The strain so suddenly given this levee could scarcely be expected to create more damage than was effected. From Mr. A. Le Jeune, who controlled a patrol force on the Point Manoir front, I learned that he passed over where the break occurred but a few minutes before same took place on a tour of inspection. As he returned he observed a large stream of water issuing from the rear slope about half-way up and dispatched his companion for a force of men, but only a few minutes elapsed before the crown of the levee fell in, and the material of sand and light loam washed rapidly and within the half-hour a large and angry break was operating. This break is located at the lower end of the levee and is in the main curtain, the south end resting at the angle where wing turns to meet old levee on front. The break occurred a little near the present north end and extended rapidly down-stream. At present, since closure at Hermitage referred to below, the break is entirely dry. Virtually no scouring took place. The surface of virgin soil is barely more than broken in places, in others undisturbed. The work was so clean yet indestructive as to clear the rear ditch of material placed in it, giving it the appearance of just having been cut.

Statement.

	Feet.
Height of levee	1[illegible]
Water below grade at time of break	[illegible]
Width of break	571

At Hermitage Landing the Point Manoir Crevasse was closed. Operations were directed by Mr. Martin Glynn, assisted by the Sewall Brothers, with their pile piling. Work was commenced on the 9th of May and concluded May 17. Work was commenced on north end. When about midway across the draught became so great that the Sewall piling could not be driven securely, and after two unsuccessful attempts a line of cribbing and sacks similar to that used at Preston was established, circular in shape on the front side. The current checked, the Sewall piling was continued, but from that point to southern juncture with levee a strong re-enforcement of sacks was placed as high as present water-line in front of this Sewall pile

soundings were taken at each 100 feet along the crib-work. At highest stage water was just above grade of old levees and held by a line of planking and sacks.

Statement.

Water when break occurred, below highest water	feet..	2.30
Present water, below highest water	do...	4.20
Length of piling	do...	980.00
Average depth of water	do...	2.82
Area of discharge	sq. feet..	2,763.60

After a short run the

LOBDELL CREVASSE

was arrived at. Mr. A. A. Alford, the manager of the Lobdell Plantation, was seen, and says that the break occurred at 4.30 p. m., April 22. The levee is a large and high one, standing 1.7 feet above the highest water of this season. It has a wide crown and good full slopes, and the entire levee is well sodded with closely cropped Bermuda grass. I was told the only weakness noticeable during the flood was a free seepage of water through the extreme base of levee, and also through the ground on which it rested. Just behind the levee and very near where the breach was made, there lived an old negro who says that suddenly there burst out of the ground immediately at the foot of the rear slope of the levee a large spout of water as large as a flour-barrel. In a very few seconds the top of the levee collapsed. The crevasse enlarged rapidly for ten days. The enlargement traveled up-stream mainly, the break having taken place near the present south end. No change in past two weeks at south end; less than 50 feet have broken off of the north end. Immediately in front of the levee is a high batture, thickly grown with timber, over which flows not more than 1 foot of water. The deepest water and greatest discharge is near each end, particularly the north end, where there is an open and deep channel.

Statement.

	Feet.
Height of levee	10.000
Water below levee when break occurred	1.700
Water below levee at present	7.500
Average velocity of nine measurements per second	4.117
Average depth of twenty-seven measurements	7.221
Width	1,981.000

Discharge 58,892.81 cubic feet per second.

On the morning of May 23, the date of foregoing measurements, the steamer *Dacotah* arrived with men and material in charge of the Sewall Brothers, and commenced a line of cribbing. No assistance is being lent in this work by the United States Government. The Sewalls do not intend under the present plan to continue their crib-work all the way around, and fully stop the crevasse. They propose to cut off the supply and decrease the discharge so that the then small amount of water escaping will cause no inconvenience to the planting interest. Their plan will be a failure. As soon as the current in the chute they are trying to dam is thrown against the sand lump they intend joining, it is almost a positive fact that it will destroy it and leave no terminus for the piling other than the almost perpendicular bank of the river. Admitting that their prospective terminus will hold, it is reasonable to suppose that the batture immediately in front of the crevasse, being of sand, will rapidly give way and assume a capacity equal to that now furnishing the crevasse.

Leaving Lobdell, a run of about 30 miles brought us to

MARTINEZ BREAK,

situated about 12 miles below Baton Rouge, in East Baton Rouge Parish, and on the east bank of the Mississippi River.

Dr. John T. Jones was seen and furnished information concerning the break, which he says was occasioned by the washing out of a rice flume, and occurred in the night of April 22, during a heavy wind and rain storm. The water was just .3 foot under the grade of the levee, and now and then the waves, dashing with great violence against the line of planking that had been put down at the low places in the levee, would run over. This break enlarged to its present width within twenty-four hours, when the ends were secured. Work of closing was inaugurated April 24 and completed on April 28.

Statement.

Height of levee	feet..
River below grade at time of break	do...
River below grade at date of measurement	do...
Water inside of break at date of measurement	do...
Average depth of seven measurements at crib	do...
Width	do...
Area of discharge	square feet..

Between the ends of cribbing and ends of break there were 234 feet of leve rowed and filled in sacks to put in break.

The *Ruby* was now headed for Baton Rouge, which place was reached abou m. of May 23. The entire measurement of the foregoing crevasses consumed ex two days' work. My movements were much expedited by meeting at each cre some one from whom an authentic history of the break with dates, etc., was obt

The *Ruby* was ordered back to Simmesport, and departed from Baton Rouge a a. m., May 24. I left a few moments later by train for New Orleans, reaching h noon.

Very respectfully, your obedient servant,

W. J. HARDEE,
Assistant Engine

Capt. DAN. C. KINGMAN,
Corps of Engineers, U. S. A.

COMMERCIAL STATISTICS.

CUSTOM-HOUSE, NEW ORLEANS, LA.,
Collector's Office, June 9, 18

SIR: Inclosed please find reports from the deputy collector and auditor cover the statistical information asked for in your letter of the 19th ultimo.

Respectfully yours,

W. L. MCMILLEN,
Special Deputy Collecto

Capt. DAN C. KINGMAN,
Corps of Engineers, U. S. A.

	Entrances.		Clearances.	
	Number.	*Tons.*	*Number.*	*Ton*
Steam	984	1,261,908	980	1,2
Sail	160	79,904	144	6
Estimate for June:				
Steam	64	78,000	64	7
Sail	15	8,000	15	
Total	1,223	1,427,812	1,203	1,4

Total value of exports, foreign merchandise, to foreign countries.

From July 1, 1889, to June 1, 1890	$759,56
Estimate for June, 1890	85,19
Total	844,76
Total value of foreign specie exported	28,68
Total value of domestic exports July 1, 1889, to May 30, 1890, inclusive	105,263,01
Estimated value for June, 1890	1,741,75
Total domestic exports for year ending June 30, 1890	107,004,76
Total foreign exports for year ending June 30, 1890	844,76
Total all exports for year ending June 30, 1890	107,849,53

Imports of specie and merchandise, free and dutiable.

Gold bullion	$17,726.00
Silver bullion	4,491.00
American gold coin	657.00
American silver dollars	1,476.00
Foreign silver dollars	420,866.00
Total for eleven months	445,216.00
Estimated for June, 1890	25,000.00
Total for twelve months	470,216.00
Also United States currency	32,320.00

Merchandise, free and dutiable.

Imports for eleven months:	
Free	$7,138,270.00
Dutiable	6,323,207.00
Total for eleven months	13,461,477.00
Estimated for June, 1890:	
Free	718,900.00
Dutiable	702,100.00
Total for month of June, 1890	1,421,000.00
Total for year ending June 30, 1890:	
Free	7,857,170.00
Dutiable	7,025,307.00
Total for year ending June 30, 1890	14,882,477.00
Collections for account of "Duties on Imports" for eleven months ending May 31, 1890	2,478,062.33
Estimate for June, 1890	175,000.00
Total for year ending June 30, 1890	2,653,062.33

Statement showing the amount and value of commerce passing out of Red River and its tributaries through Old River into the Mississippi River, compiled by Mr. W. J. Hardee, assistant engineer, from the river column of the New Orleans Daily States, and from assistance furnished by the commercial exchanges of New Orleans, Louisiana.

[The period embraced by this report extends from June 1, 1889, to June 1, 1890.]

STATEMENT.

Number of steam-boats	20
Trips made by them	318
Net tonnage of same	108,130
Number of barges	16
Net tonnage of barges	9,600
Total tonnage of steam-boats and barges	117,730
Total cargo brought (tons)	106,416
Value of same	$10,022,798

ARTICLES OF CARGO.

Apples	barrels	18	Eggs	packages	3,130
Apples, dried	do	6	Excelsior	bales	201
Bones	sacks	441	Flour	barrels	52
Bottles (empty)	barrels	612	Furniture	packages	132
Cattle	head	138	Grits	barrels	131
Cabbage	crates	6	Hides	loose	418
Corn	sacks	80	Hides	packages	1,195
Cotton	bales	170,912	Hogs	number	754
Cotton seed	sacks	595,189	Honey	barrels	79
Cotton-seed meal	sacks	21,646	Horses and mules	head	20
Cotton-seed oil	barrels	3,101	Kegs (empty)	number	158

ARTICLES OF CARGO—continued.

Lumber	feet B. M.	508,799	Sheep	head	
Moat	bales	30	Skins	packages	
Moss	do	1,313	Sugar	hogsheads	
Molasses	barrels	13,062	Sugar	barrels	
Miscellaneous	packages	250	Screenings	sacks	
Pecans	barrels	61	Seed-cotton	do	
Potatoes	do	170	Staves (oak)	number	
Potatoes	sacks	301	Saw-logs, 10-foot lengths (no count made of tonnage)		
Poultry	coops	83			
Pork	barrels	56	Tallow	barrels	
Peas	do	41	Wheels	bundles	
Peas	sacks	44	Wool	bags	
Rice	barrels	10	Wood	cords	
Rice	sacks	10,258			

This does not include the up-stream freights which must be nearly equal to down-stream ones.

Statement showing the river arrivals at New Orleans, Louisiana, from June 1, 18[illegible] June 1, 1890, compiled by Mr. W. J. Hardee, assistant engineer, from the river [illegible] of the New Orleans Daily States, and from assistance furnished by the commercial changes of New Orleans, Louisiana.

ABOVE THE CITY.

Steam-boats (number)	[illegible]
Trips made by them	1,3[illegible]
Net tonnage of same	547,[illegible]
Tow-boats (number)	[illegible]
Trips made by them	[illegible]
Net tonnage of same	70,[illegible]
Barges (number)	1,[illegible]
Net tonnage of same	472,[illegible]
Number of luggers (sailing)	[illegible]
Trips made by them	[illegible]
Net tonnage of same	1,1[illegible]
Total tonnage (steam-boats, tow-boats, barges, and luggers)	1,097,[illegible]
Total cargo brought (tons)	1,716,[illegible]
Value of same	$64,619,[illegible]

BELOW THE CITY.

Steam-boats in local trade	[illegible]
Trips made by them	18[illegible]
Net tonnage of same	18,[illegible]
Luggers (sailing) in local trade	2[illegible]
Trips made by them	4,[illegible]
Net tonnage of same	123,[illegible]
Total tonnage (steam-boats and luggers)	141,[illegible]
Total cargo brought (tons)	19,[illegible]
Value of same	$1,612,[illegible]

RECAPITULATION.

Total arrivals, above (steam-boats, tow-boats, barges, and luggers)	2,64[illegible]
Total net tonnage	1,097,[illegible]
Total arrivals from below	4,[illegible]
Total net tonnage	141,[illegible]

ARTICLES OF CARGO.

Acids	carboys	1,570	Barrel linings	bundles	2,0[illegible]
Alcohol	barrels	22	Barley	sacks	13[illegible]
Ammonia	drums	100	Beans	barrels and sacks	1,1[illegible]
Apples	barrels	1,222	Buggies	number	11
Apples, dried	do	1,078	Bungs	barrels	17[illegible]
Buckets	dozen	3,085	Beef	do	91
Bagging	rolls	26,273	Bacon	do	50[illegible]
Baking-powder	boxes	118	Beer	packages	3,0[illegible]
Barrels (empty)	number	2,065	Bitters	boxes	5,9[illegible]

ARTICLES OF CARGO—continued.

›nes	sacks	697
›an	do	99,122
›ushes	boxes	43
›lts and nuts	kegs	520
›oom-corn	bales	2,198
›llows	number	21
lueing	cases	3
ricks, fire	number	1,165
utter	packages	270
ottles (empty)	barrels	2,091
randy	do	1
askets	bundles	544
andles	boxes	2,111
ordials	do	1
attle	head	298
rackers	boxes	51
abbage	crates	1,275
heese	cases	11
anned goods	boxes	135
ork	bags	1
arts	number	47
ement	barrels	1,550
andy	packages	699
artridges	cases	12
arriages	number	3
ider	packages	275
oal	bushels	10,580,000
oke	do	133,000
orn	do	14,107,385
orn	sacks	323,679
ross-ties	number	12,000
otton	bales	467,716
otton-seed	sacks	1,920,959
otton-seed meal	do	72,682
otton-seed ashes	do	702
arbons	boxes	2,828
otton-seed oil	barrels	6,014
orn-meal	do	99,328
orn-meal	sacks	3,719
hains	casks	845
igars	cases	1
rockery	packages	5,681
astings	do	1,666
rugs	do	4,122
ry goods	do	4,394
ggs	do	7,368
xcelsior	bales	1,555
elloes	bundles	6,566
eed meal	sacks	9,177
ire-clay	barrels	505
lour	do	329,128
lour	half-barrels	53,377
lour	sacks	6,204
ruits, dried	packages	30
urniture	do	20,598
urnaces	number	40
lax-seed	sacks	25
rindstones	number	4,080
in	barrels	12
arlic	strings	1,208
lass	packages	7,000
lassware	do	8,051
uano	sacks	170
lucose	barrels	1,202
roceries	packages	11,119
lue	barrels	11
rits	do	58,058
ubs	bundles	699
Hops	bales	2
Hams	cases	787
Hair	bales	2,450
Hay	do	8,232
Hay	half bales	12,452
Hay	quarter bales	9,664
Hides, loose		747
Hides	packages	2,336
Hogs	head	946
Honey	barrels	326
Hoop-poles	number	371,613
Horses and mules	head	353
Hominy	barrels	297
Hose	package	1
Handles	bundles	4,553
Hinges	barrels	277
Horns	sacks	6
Hardware	packages	11,002
Iron	do	23,046
Ink	boxes	209
Irons, heating	do	308
Kraut	barrels	241
Kegs (empty)	number	1,872
Lard	packages	37,630
Lead, pigs	number	1,611
Lead, sheet	boxes	505
Lye	cases	55
Linseed-meal	sacks	5
Lime	barrels	3,887
Lumber	feet B. M	1,342,633
Mops	dozen	233
Mattresses	number	245
Mattresses, wire	do	439
Mucilage	boxes	219
Moat	bales	383
Mats	dozen	88
Molding	bundles	12
Moss	bales	7,586
Malt	sacks	17,681
Molasses	barrels	169,758
Milk	cases	1
Mirrors	boxes	2,250
Meat	cases	124
Miscellaneous	packages	32,042
Nails	kegs	53,800
Oysters (shell)	barrels	2,070,000
Oats (bulk)	bushels	49,707
Oats	sacks	434,091
Oatmeal	barrels	78
Oil	do	3,780
Oil-cake	sacks	73,035
Onions	barrels	3,131
Onions	sacks	34,162
Oranges	barrels	27,591
Oranges	boxes	58
Pots	number	1,524
Pipe	packages	2,601
Plows	number	4,605
Pecans	barrels	131
Pickles	do	99
Pickles	cases	8,589
Potatoes	barrels	94,717
Potatoes	sacks	69,769
Poultry	coops	412
Preserves	cases	273
Pork	barrels	339
Putty	do	51
Pitch	do	47

ARTICLES OF CARGO—continued.

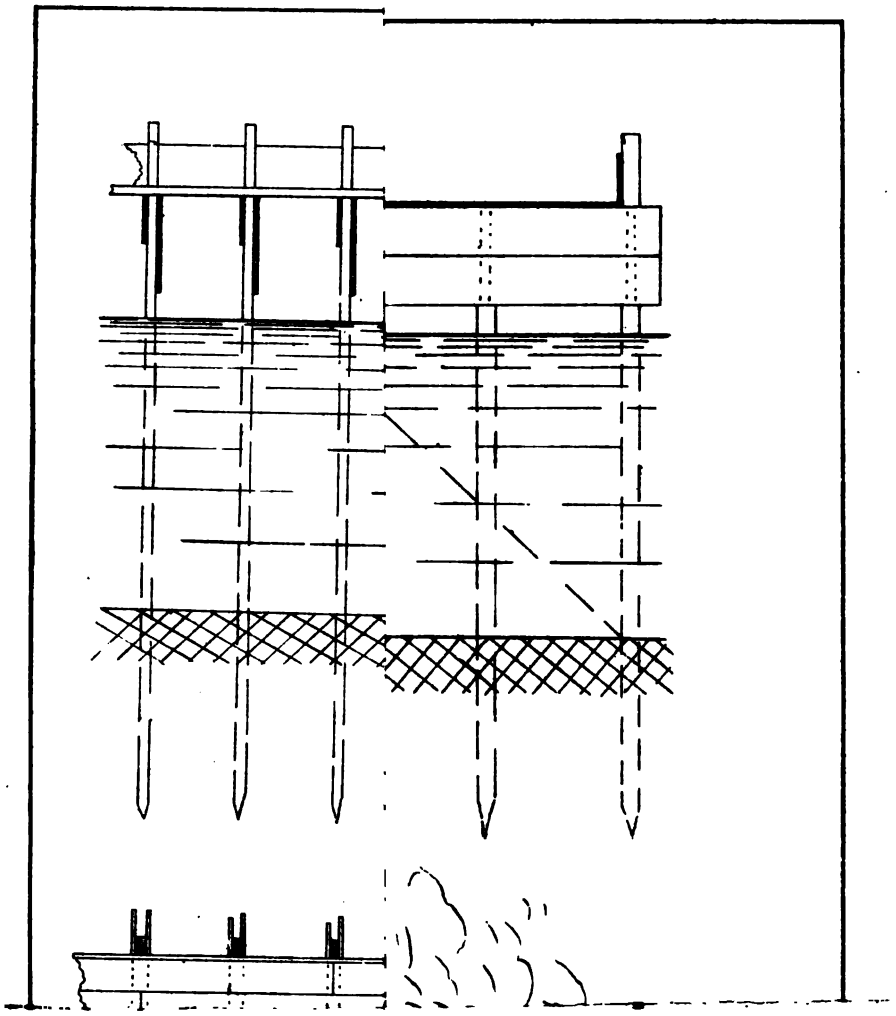
Paint	packages	282	Saddlery	packages	
Peanuts	bags	2,279	Spikes	kegs	
Peas	barrels	339	Sirup	barrels	
Peas	sacks	733	Steel-wire	packages	
Pumps	number	59	Shrimp	boxes	
Paper	bundles	419	Show-cases	number	
Rope	bales	7,042	Saw-logs, 10-foot lengths (no count made of tonnage)		
Rye	bushels	175,000	Twine	bundles	
Rags	bales	113	Tallow	barrels	
Rice	barrels	2,153	Tiles	pieces	
Rice	sacks	433,036	Tobacco	hogheads	
Rings	bundles	5	Tobacco	cases	
Sheep	number	397	Toys	packages	
Shot	pockets	4,084	Tubs	packages	
Sirup of figs	boxes	750	Tin-ware	packages	
Skins	packages	43	Trunks	number	
Soap	boxes	6,066	Varnish	barrels	
Soap-stock	barrels	306	Vegetables	packages	
Single-trees	bundles	1,512	Vinegar	barrels	
Starch	barrels	687	Wooden ware	packages	
Starch	boxes	45,296	Wool	bags	
Sacks	bales	66	Wax	barrels	
Stone	pieces	19	Washboards	number	
Shoes	cases	174	Wagons	do	
Spades and shovels	bundles	262	Wheat (bulk)	bushels	2,20
Seed (garden)	packages	219	Wheat	sacks	
Sash-weights	number	12,973	Wrappers	bundles	
Staples	kegs	978	Whisky	barrels	
Sugar	hogsheads	55,169	Whisky and wines	cases	
Sugar	barrels	237,054	White lead	kegs	
Straw	bales	3,684	White lead	cases	
Screenings	sacks	1,394	Wine	barrels	
Seed-cotton	do	783	Wood	cords	
Staves (oak)	number	1,716,311	Wire	reels	
Stoves	do	4,066	Wheels	bundles	
Safes, iron	do	1	Washers	bundles	
Spokes	bundles	3,079			

This list includes simply the freights brought to New Orleans by steam-boa and barges on the Mississippi River, and does not include the large and valua freights that they take away. No record is kept of this, and it is impossible to furn even a reasonably accurate estimate of its value. It would amount to a very la sum in the aggregate, probably more than fifty per cent. of the value of freights r ceived at New Orleans.

Statement showing the approximate receipts and shipments of freight by river from Jun 1889, *to June* 1, 1880, *at Natchez and Vidalia, Bayou Sara, Baton Rouge, Plaquemine, a Donaldsonville, compiled by W. J. Hardee, assistant engineer, from information deri from the commercial exchanges of the respective towns and the several business houses a landings where the steam-boats receive and discharge cargoes.*

It must be known that the above towns are, strictly speaking, "way points," a not termini; by virtue of that fact the net tonnage or carrying capacity of the steam boats that do business at those places is not given, as it would not show the prop relation between what would then be made the possible tonnage and the actual ton nage hauled. All New Orleans steam-boats are counted "arrived" when they stop o their way up the river, and "departed" when they stop on their way down to Ne Orleans. St. Louis and Ohio River steam-boats are counted "arrived" when the stop on their way down the river, and "departed" when they stop on their way u stream.

Owing to the obscure records obtainable many articles of a like character are style under one head.



BAYOU SARA, LOUISIANA.

Receipts.

Number of steam-boats in the trade	
Number of times they arrived	
Number of barges	
Total cargo arrived (tons)	
Value of same	$1,5

ARTICLES OF CARGO.

Cotton	bales	9,000	Screenings	sacks	
Coal	bushels	562,500	Grits	barrels	11
Potatoes	barrels	3,500	Soda-pop	boxes	
Corn-meal	do	37,835	Groceries	packages	
Flour	do	14,697	Furniture	do	
Pork	do	7,101	Hardware	do	
Corn	sacks	30,000	Wooden ware	do	
Oats	do	75,120	Molasses	barrels	
Meat, salt	pounds	1,200,000	Sugar	do	
Soap	do	15,000	Coffee	sacks	
Lard	do	75,000	Rice	barrels	
Beer	casks	6,000	Salt	sacks	
Bagging	rolls	4,300	Tobacco	pounds	5
Ties	bundles	4,290	Miscellaneous	packages	6
Hay	bales	8,000	Fertilizers	tons	
Lime	barrels	515	Wire	coils	
Bran	sacks	6,000	Ice	tons	

Shipments.

Number of steam-boats in the trade	
Number of times departed	1
Total cargo shipped (tons)	9
Value of same	$1,696,1

ARTICLES OF CARGO.

Cotton	bales	27,000	Cement	barrels	
Cotton seed	sacks	90,000	Bran	sacks	1,5
Lumber	feet B. M.	626,000	Screenings	do	1,6
Potatoes	barrels	1,875	Grits	barrels	8,5
Corn-meal	do	9,458	Groceries	packages	3,1
Flour	do	3,677	Furniture	do	
Pork	do	1,775	Hardware	tons	
Corn	sacks	7,500	Wooden-ware	packages	3,5
Oats	do	18,780	Molasses	barrels	
Meat, salt	pounds	300,000	Sugar	do	
Soap	do	3,750	Coffee	sacks	
Lard	do	18,750	Rice	barrels	
Bagging	rolls	1,078	Salt	sacks	
Ties	bundles	1,078	Tobacco	pounds	8,2
Hay	bales	6,000	Miscellaneous	packages	1,5
Lime	barrels	178	Wire	coils	1,2

RECAPITULATION FOR BAYOU SARA, LOUISIANA.

Total cargo received (tons)	20,063
Total value of same	$1,696,199
Total cargo shipped (tons)	50,717
Total value of same	$1,589,979
Total cargo received and shipped (tons)	70,800
Total value of same	$3,286,178

ARTICLES OF CARGO.

Receipts.

Potatoes	barrels	2,609	Coffee	sacks	
Onions	do	780	Liquors	barrels	
Corn-meal	do	7,566	Vinegar	do	
Flour	do	10,088	Oils	do	
Grits	do	2,275	Dry goods	packages	
Hay	bales	1,235	Miscellaneous	do	
Corn	sacks	8,970	Lime	barrels	
Oats	do	14,950	Pork and beef	do	
Bran (wheat)	do	2,795	Meat (salt)	boxes	
Bran (rice)	do	1,560	Fruits	packages	
Groceries	packages	49,355	Oysters	barrels	
Hardware	do	3,257	Machinery	tons	
Wooden-ware	do	1,497	Crockery	packages	
Sugar	barrels	1,352	Furniture	do	
Molasses	do	312	Coal	bushels	1,
Rice	do	1,040			

Shipments.

Number of steam-boats in the trade	
Number of times they departed	
Number of barges	
Tonnage shipped	4
Value of same	$

ARTICLES OF CARGO.

Lumber	feet, B. M.	10,075,000	Hides (loose)	number	1
Shingles		89,000,000	Fish	pounds	
Sugar	hogsheads	1,000	Potatoes	barrels	
Molasses	barrels	4,000	Onions	do	
Moss	bales	5,000	Honey	do	

RECAPITULATION FOR PLAQUEMINE.

Total cargo received	tons
Value of same	$6
Total cargo shipped	tons 41
Value of same	$64
Total cargo received and shipped	tons 93
Total value of same	$1,2

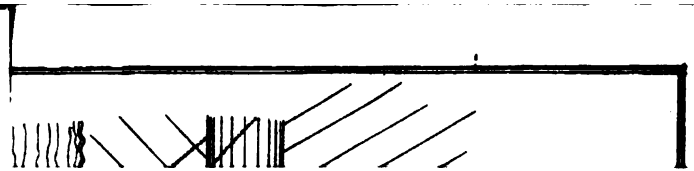
DONALDSONVILLE, LOUISIANA.

Receipts.

Number of steam-boats in the trade	
Number of times they arrived	
Number of barges	
Total cargo received	tons 84
Total value of same	$92

ARTICLES OF CARGO.

Corn-meal	barrels	2,070	Crockery	packages	2
Flour	do	4,565	Lime	barrels	
Grits	do	1,742	Miscellaneous	packages	1
Meat (salt)	boxes	1,040	Fruits	do	1
Liquors	barrels	686	Oysters	barrels	1
Oils	do	1,030	Onions	do	1
Vinegar	do	103	Lumber	feet, B. M.	85
Corn	sacks	10,400	Potatoes	barrels	2
Oats	do	26,000	Acids	carboys	
Hay	bales	2,080	Wood	cords	1
Bran (wheat)	sacks	1,560	Coal	bushels	1,836
Bran (rice)	do	2,300	Sugar	barrels	1
Groceries	packages	41,000	Molasses	do	
Hardware	do	2,290	Rice	do	1
Wooden ware	do	1,420	Coffee	sacks	2
Dry goods	do	1,148			



Shipments.

umber of steam-boats in the trade	27
umber of times they departed	742
otal cargo shipped ..... tons..	1,435
alue of same	$135,250

ARTICLES OF CARGO.

ugar	barrels..	6,600	Hides	number..	250
olasses	do....	2,100	Miscellaneous	packages..	2,650

RECAPITULATION FOR DONALDSONVILLE, LOUISIANA.

onnage received	84,969
alue of same	$669,325
onnage shipped	1,435
alue of same	$135,250
otal tonnage received and shipped	86,404
otal value of same	$804,575